

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LXXIII.

FEBRUARY 14, 1913.

No. 4

ANNUAL GENERAL MEETING.

F. W. DYSON, Esq., M.A., LL.D., F.R.S., PRESIDENT, in the Chair.

The Report of the Auditors of the Treasurer's accounts for the year 1912 was read, and is given on p. 198.

The Annual Report of the Council was partly read; see pp. 195 to 311.

The Address was delivered by the President, who gave an account of the grounds on which the Gold Medal had been awarded to M. Henri Alexandre Deslandres, for his investigations of Solar Phenomena and other spectroscopic work. The Medal was then handed to M. Roux, Secretary of the French Embassy, for transmission to M. Deslandres (see pp. 317 to 329).

After a further Address, the President handed the Jackson-Gwilt Medal and Gift to the Reverend T. H. E. C. Espin, to whom they had been awarded for his observations of the Spectra of Stars and his discovery of Nova Lacertæ (see p. 330).

The President having appointed the Scrutineers, the Society proceeded to the ballot for Officers and Council for the ensuing year. The names of those elected are given on p. 331.

Major E. H. Hills, C.M.G., F.R.S., then took the chair as President.

The thanks of the Meeting were given to the retiring Officers and Members of Council, and also to the Auditors of the Treasurer's accounts and to the Scrutineers of the ballot.

Albert Henry Stewart Gillson, B.A., St. John's College,
Cambridge;

Daniel Hogarth, c/o Mr. C. G. M'Crea, 11 Macquarie Place,
Sydney, New South Wales, Australia;

Donald William Horner, F.R.Met.Soc., Milford, Ellington
Avenue, Westgate-on-Sea; and

William Petersen, 32 Inverness Terrace, Hyde Park, W.,

were balloted for and duly elected Fellows of the Society.

The following Candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

E. A. Fath, Director of the Smith Observatory, Beloit College,
Beloit, Wisconsin, U.S.A. (proposed by Prof. H. H. Turner);

Rev. George Harold Lancaster, M.A., 6 Dartmouth Road,
Brondesbury, N.W. (proposed by Prof. H. H. Turner);

Maurice Egerton Leigh-Hunt, Queen's Hill, Hertford, Herts
(proposed by E. W. Maunder);

Rev. James Marchant, Lochnagar, Eden Bridge, Kent (pro-
posed by G. F. Chambers); and

William Alfred Parr, 19 Rosslyn Hill, Hampstead, N.W.
(proposed by E. W. Maunder).

REPORT OF THE COUNCIL TO THE NINETY-THIRD ANNUAL
GENERAL MEETING OF THE SOCIETY.

The following table shows the progress and present state of the Society:—

	Patron	Honorary Members	Fellows		Associates	Total
			Compounders	Annual Subscribers		
1911 December 30	1	1	254	455	49	760
Since elected	...	...	+ 1	+ 36	+ 1	...
Deceased	...	...	- 6	- 5	- 2	...
Resigned	...	...	...	- 6	...	...
Since compounded	...	...	...	...	...	...
Removed	...	...	...	- 8	...	...
1912 December 31	1	1	249	472	48	771

Major Hills' Account as Treasurer of the Royal

RECEIVED.

Balances, 1911 December 30 :—	£	s.	d.	£	s.	d.
At Bankers', as per Pass-book	243	13	10			
In hand of Assistant Secretary on Account of Council Grant for purchase of Books ...	9	16	7			
In hand of Assistant Secretary on Petty Cash Account	4	8	6			
				257	18	11
Dividends :—						
£1,250 Metropolitan 3-per-cent. Stock ...	35	6	4			
£2,000 Swansea Corporation 3½-per-cent. Stock	65	18	4			
£3,500 East Indian Railway 3-per-cent. Debenture Stock	98	17	4			
£3,500 London and North-Western Railway 3-per-cent. Debenture Stock	98	17	6			
£4,000 Midland Railway 2½-per-cent. Debenture Stock	94	3	4			
£1,000 Lancashire and Yorkshire Railway 3-per-cent. Preference Stock	28	5	0			
£2,000 Gas Light and Coke Co. 3-per-cent. Debenture Stock	56	10	0			
£2,000 Commercial Gas Co. 3-per-cent. Debenture Stock	56	10	0			
				534	7	10
Received on account of Subscriptions :—						
Arrears	178	18	0			
Annual Contributions for 1912	701	8	0			
„ „ in advance	12	2	0			
Admission Fees	75	12	0			
First Contributions	50	8	0			
				1,018	8	0
Composition Fee				31	10	0
Sales of Publications :—						
At Society's Rooms, 1912	79	0	6			
At Williams & Norgate's, 1911	14	13	1			
At Wesley & Son's, 1912	52	13	4			
Half share of proceeds of sale of Sir W. Herschel's Collected Scientific Papers, received from the Royal Society	56	2	9			
				202	9	8
Sales of Photographs				44	18	0
Income Tax refunded by Commissioners of Inland Revenue				33	2	2

 £2,122 14 7

Examined and found correct, January 8, 1913.

J. W. CAPSTICK.
W. HEATH.
J. R. LEESON.

Astronomical Society from January 1 to December 31, 1912.

PAID.					£	s.	d.	£	s.	d.
Assistant Secretary: Salary	...	...	...	...	250	0	0			
Clerk's Salary	...	...	...	...	100	0	0			
House Duty	...	...	...	...	2	12	6	400	0	0
Fire and Servants' Insurance	...	...	...	...	9	15	9			
Printing, etc. :—										
<i>Monthly Notices</i>	...	...	...	...	458	17	5			
Lists of Fellows, etc. etc.	...	...	...	...	30	18	0			
Miscellaneous (Circulars, etc.)	...	...	...	...	9	10	9			
Photo-engraving for <i>Monthly Notices</i>	...	...	...	...	9	5	2			
Sir W. Herschel's Collected Scientific Papers: half share of cost of production... ..	...	...	...	...	415	17	8	924	9	0
Cataloguing Astronomical Literature for the Inter- national Catalogue	...	...	...	...				30	0	0
Reproduction of Photographs for sale	...	...	...	...				24	10	8
Turnor and Horrox Fund, and Council Grant for purchase of Books for Library	...	...	...	...	21	0	4			
Binding for Library	...	...	...	...	34	18	3			
Expenses of Meetings	...	...	...	...	18	2	8	55	18	7
Lantern attendance	...	...	...	...	4	0	0			
Time Signal: Rental of wire... ..	...	...	...	...	5	0	0			
Ventilating fan, etc., for Meeting-Room	...	...	...	...	28	5	0			
Subsn. to <i>Centralstelle für astronomische Telegramme</i>								55	7	8
Telephone Subscription	...	...	...	...	6	10	0	1	13	3
Registration of Telegraphic Address	...	...	...	...	1	1	0			
Postage and Telegrams	...	...	...	...	87	14	11			
Carriage of Parcels	...	...	...	...	0	12	10			
Stationery and Office expenses	...	...	...	...	18	3	9			
Typewriter for Office	...	...	...	...				114	2	6
House expenses: Allowance and sundry expenses	...	...	...	...	55	10	4	10	7	0
Coal, Gas, and Electric Light	...	...	...	...	58	10	1			
Sundry fittings and repairs	...	...	...	...	6	0	10			
Sundries	...	...	...	...	5	0	5	125	1	8
Gold Medals	...	...	...	...	52	12	6			
Engrossing Address to Royal Society	...	...	...	...	3	13	6			
Barcelona Exhibition: Sundry expenses	...	...	...	...	2	10	6			
Lee and Janson Fund: Grants to Mrs. M'Dowell								58	16	6
Bankers' deductions on Cheques	...	...	...	...				15	0	0
Balances, 1912 December 31 :—										
At Bankers', as per Pass-book	...	...	...	...	279	18	10			
Not credited till 1913	...	...	...	...	11	0				
In hand of Assistant Secretary on Account of Turnor and Horrox Fund	...	...	...	...	3	16	3			
On Petty Cash Account	...	...	...	...	10	8	8	294	14	9
								<u>£2,122 14 7</u>		

Report of the Auditors.

We have examined the Treasurer's account of receipts and expenditure for the year 1912, and have found and certified the same to be correct. The cash in hand on December 31, 1912, including the balance at the bankers', etc., amounted to £294 14s. 9d.

The funded property of the Society is the same as at the end of the previous year.

The books, instruments, and other effects in the possession of the Society have been examined, and they appear to be in a satisfactory condition.

A list has been laid on the table of the names of those Fellows who are in arrear for sums due at the last Annual General Meeting of the Society, together with the amount due against each Fellow's name.

(Signed) J. W. CAPSTICK.
W. HEATH.
J. R. LEESON.

1913 January 16.

Gifts to the General Funds of the Society.

In 1836 John Lee, Esq., LL.D., gave the Advowson of the living of Hartwell; in 1844 he gave the Advowson of the living of Stone, Bucks. In 1879 these Advowsons were repurchased by his heir, Edward Lee, Esq., for £700.

The Lawson Bequest (1856): Henry Lawson, Esq., bequeathed to the Society the sum of £200, free of legacy duty.

The Carrington Bequest (1876): R. C. Carrington, Esq., F.R.S., bequeathed to the Society £2,000 Consols. This was sold in 1899, and stands now in £1,881 14s. London and North-Western Railway 3-per-cent. Debenture Stock.

The Lambert Bequest (1877): C. J. Lambert, Esq., presented to the Society the sum of £500, free of legacy duty, being part of a sum of money bequeathed by his father, Charles Lambert, Esq., for scientific purposes.

The McClean Bequest (1905): Frank McClean, Esq., LL.D., F.R.S., bequeathed to the Society the sum of £2,000, free of legacy duty. This now stands in £1,871 1s. 6d. Swansea Corporation 3½-per-cent. Stock.

The Farrar Bequest (1906): The Rev. A. S. Farrar, D.D., bequeathed to the Society the sum of £100, free of legacy duty. This now stands in £93 11s. 1d. Swansea Corporation 3½-per-cent. Stock.

Trust Funds.

The Lee and Janson Fund: In 1834 John Lee, Esq., LL.D., gave £100, and in 1876 T. C. Janson, Esq., bequeathed £200, the interest to be given to the widow or orphan of a deceased Fellow. These amounts now stand in £334 10s. 9d. East Indian Railway 3-per-cent. Debenture Stock.

	£	s.	d.		£	s.	d.
1912 Jan. 1. Balance of				1912. Grants to Mrs			
Fund	79	17	1	M'Dowell	15	0	0
Dividends, East Indian				1912 Dec. 31. Balance of			
Railway	10	0	9	Fund	74	17	10
	<u>£89</u>	<u>17</u>	<u>10</u>		<u>£89</u>	<u>17</u>	<u>10</u>

The Turnor Fund and the Horrox Memorial Fund: In 1853 the Rev. Charles Turnor, M.A., bequeathed a sum of £500, which now stands in £464 18s. East Indian Railway 3-per-cent. Debenture Stock. In 1876 the Society received a sum of £38 15s., the unexpended balance of a fund collected for the purpose of erecting a memorial in Westminster Abbey to Jeremiah Horrox: to this the Society added the sum of £55 15s., and the whole now stands in £103 6s. East Indian Railway 3-per-cent. Debenture Stock. The interest on these funds is to be used in the purchase of books for the Library.

	£	s.	d.		£	s.	d.
1912 Dividends, East				1912 Jan 1. Due to			
Indian Railway ...	17	1	0	Fund	7	8	
				Purchase of Books ...	15	0	0
				1912 Dec. 31. Balance of			
				Fund	1	13	4
	<u>£17</u>	<u>1</u>	<u>0</u>		<u>£17</u>	<u>1</u>	<u>0</u>

The Hannah Jackson (née Gwilt) Fund: In 1861 Mrs. Hannah Jackson (née Gwilt) gave £300 Consols, which now stands in £309 18s. 6d. East Indian Railway 3-per-cent. Debenture Stock; the interest to be given in medals or other awards in accordance with the terms of the Trust.

	£	s.	d.		£	s.	d.
1912 Jan. 1. Balance of				1912 Dec. 31. Balance of			
Fund	40	14	5	Fund	50	0	5
Dividends, East Indian							
Railway	9	6	0				
	<u>£50</u>	<u>0</u>	<u>5</u>		<u>£50</u>	<u>0</u>	<u>5</u>

Assets and Present Property of the Society, 1913 January 1.

Balances, 1912 December 31 :—

	£	s.	d.	£	s.	d.
At Bankers', as per Pass-book	279	18	10			
Not credited till 1913		11	0			
In hand of Assistant Secretary on account of Turnor and Horrox Fund	3	16	3			
In hand of Assistant Secretary on Petty Cash Account	10	8	8			
				294	14	9
Due on account of Subscriptions :—	£	s.	d.			
18 Contributions of 3 years' standing	113	8	0			
35 " 2 " "	147	0	0			
62 " 1 " "	130	4	0			
3 Admission Fees and First Con- tributions	9	9	0			
1 other sum	4	0	0			
				404	1	0
Less Contributions paid in advance		12	2	0		
				391	19	0
Due from Wesley & Son for sales of Publications during last quarter of 1912				27	10	¹⁰ / ₁₀

£1,250 Metropolitan 3-per-cent. Stock.

£2,000 Swansea Corporation 3½-per-cent. Stock (including the McClean and Farrar Bequests).

£3,500 East Indian Railway 3-per-cent. Debenture Stock (including the Turnor Fund, the Horrox Memorial Fund, the Lee and Janson Fund, and the Hannah Jackson (*née* Gwilt) Fund).

£3,500 London and North-Western Railway 3-per-cent. Debenture Stock (including the Carrington Bequest).

£4,000 Midland Railway 2½-per-cent. Debenture Stock.

£1,000 Lancashire and Yorkshire Railway 3-per-cent. Consolidated Preference Stock.

£2,000 Gas Light and Coke Co. 3-per-cent. Debenture Stock.

£2,000 Commercial Gas Co. 3-per-cent. Debenture Stock.

Astronomical and other Manuscripts, Books, Prints, Photographs, and Instruments.

Furniture, &c.

Stock of Publications and Photographs.

Four Gold Medals.

Celestial Photographs.

No additions have been made to the list given in the last Report.

The Award of the Gold Medal.

The Council have awarded the Society's Gold Medal to M. Henri Alexandre Deslandres for his investigations of Solar Phenomena and other Spectroscopic work. The President will lay before the Society the grounds upon which the award has been founded.

The Jackson-Gwilt Medal and Gift.

The Council have awarded the Jackson-Gwilt Medal and Gift to the Rev. T. H. E. C. Espin for his observations of the Spectra of Stars and his discovery of Nova Lacertæ.

Publications of the Society.

During the past year vol. lxxii. of the *Monthly Notices* has been published.

By an oversight the publication of the General Index to vols. liii. to lxx. of the *Monthly Notices* was not announced in last year's Annual Report. This index, prepared by Mr. Levander, under the direction of the Secretaries, was on the same lines as the previous General Index, to vols. xxx. to lii., but it also contains a General Index to the illustrations in vols. i. to lix. of the *Memoirs* and vols. i. to lxx. of the *Monthly Notices*, which was kindly prepared by Mr. Knobel. A list of comets from 1890 to 1911, kindly drawn up by Dr. Crommelin in continuation of the list in the previous General Index, forms an Appendix to the volume.

During the past year there has also been published under the direction of a joint committee of the Royal Society and the Royal Astronomical Society the *Collected Scientific Papers of Sir William Herschel*. The expense has been shared equally by the two Societies. The work was edited by Dr. J. L. E. Dreyer, who contributed a biographical introduction based largely on hitherto unpublished material placed at the disposal of the committee by Sir W. J. Herschel, Bart. The price of the two volumes is £2, 10s. net; they may be obtained from Messrs Dulau & Co., Soho Square, or through any bookseller.

OBITUARY.

The Council regret that they have to record the loss by death of the following Fellows and Associates during the past year:—

Fellows :—Joseph Ibbitson Berry.
Robert Holford M. Bosanquet.
Sir Gainsford Bruce.
Robert Courtenay.
Sir George Howard Darwin.
John Franklin-Adams.
Arthur Ernest Hodgson.
Isaac Molloy.
Richard Munday.
Walter A. Post.
Samuel Arthur Saunder.

Associates :—Lewis Boss.
Henri Poincaré.

An obituary notice is also given of Lewis Swift, who died in 1913.

ROBERT HOLFORD MACDOWALL BOSANQUET was born 1841 July 31. He was the second son of the Rev. R. W. Bosanquet of Rock Hall, Alnwick, Northumberland. The family is one of remarkable talent. One of his brothers, Admiral Sir Day Bosanquet, G.C.V.O., is now Governor of South Australia; another surviving brother, Dr. Bernard Bosanquet, was formerly Professor of Moral Philosophy in the University of St. Andrews.

Mr. R. H. M. Bosanquet was educated at Eton and at Balliol College, Oxford, where he took first-class honours in Natural Science and Mathematics, and afterwards became Fellow of St. John's College. Though called to the Bar at Lincoln's Inn, he devoted himself mainly to tutorial work at Oxford, where on several occasions he was examiner in the Natural Science School. Between 1875 and 1890 he produced a large number of scientific papers, most of which appeared in the *Philosophical Magazine*. His researches, which were both experimental and theoretical, were at first mainly concerned with acoustical problems, particularly the theory of musical instruments and consonances; afterwards he devoted his attention to electromagnetism. These investigations won for him the distinction of being elected a Fellow of the Royal Society in 1890.

He was much interested in astronomy, and contributed papers to the *Monthly Notices* and *Astronomische Nachrichten*. Among his earliest papers was a modification of Olbers' method of determin-

ing a parabolic orbit from observations. He also, in conjunction with Professor Sayce, contributed a series of papers to the Society on Babylonian astronomy.

Mr. Bosanquet was an accomplished musician, and at one time held a professorship at the Royal College of Music. He was a recognised authority on organ construction, and contributed the article "Organ (Modern)" to the latest edition of the *Encyclopædia Britannica*.

In 1876 Mr. Bosanquet published an able treatise on "Musical Intervals and Temperament," in which he very fully discussed the principles of the mean tone system and equal temperament. At the Loan collection of scientific apparatus at South Kensington in that year he exhibited an Enharmonic Harmonium which he had constructed. This instrument possessed a keyboard of four and a half octaves, containing seven tiers of keys. As each tier contained twelve keys to the octave, there were altogether eighty-four keys in each octave. The instrument was tuned according to the division of the octave into fifty-three equal intervals, a system sensibly identical with perfect fifths.

Mr. Bosanquet also invented a Polariscope for detecting faint traces of polarisation independently of its direction. In this there were two wedges of right and left-handed quartz with their axes parallel to that of the instrument, and a Nicol prism was interposed before the eye.

About 1890, owing to failing health, he settled in Teneriffe, but returned to England each year to spend the summer. His death took place at his house in Teneriffe, Castello Zamorra, 1912 August 7. He was unmarried.

He was elected a Fellow of the Society 1871 November 10.

The Rt. Hon. Sir GAINSFORD BRUCE was born in 1834. His father was a schoolmaster in the north of England. He was educated at the University of Glasgow, and afterwards entered the legal profession. He was called to the Bar in 1859. At all times his practice was mainly confined to Admiralty cases; a standard work on Admiralty practice bears his name as joint author. In 1869 he was appointed by the Council of Law Reporting, Reporter in the Admiralty and Ecclesiastical Courts, a post which he held until 1883, when he was made a Queen's Counsel. In 1879 he was appointed Solicitor-General of the County Palatine of Durham, of which in a few years he became Attorney-General and then temporal Chancellor. The Chancery Court of Durham is an important tribunal of its kind, and Bruce contrived to enhance its dignity and efficiency.

After two unsuccessful attempts, he entered Parliament as Conservative member for the Holborn division of Finsbury in 1888. He rarely spoke in the House, but took some part in the passing of the Palatine Court of Durham Act 1889. He was re-elected for Holborn in 1892, but immediately retired in order to make room for Mr. Ritchie, who had been defeated at the General Election.

He was now made a Judge of the King's Bench Division of the High Court, an appointment which he appears to have fully justified. Owing to failing health he retired from the Bench in 1904, and for the last few years of his life was an invalid.

He married in 1868 a daughter of Mr. Francis Jackson. His death took place at his residence in Southwell Park, Bromley, Kent, 1912 February 24.

He was elected a Fellow of the Society 1887 December 9.

ROBERT COURTENAY was born in London on 1851 September 17. His father was a physician who practised for the greater part of his life in Dublin.

Mr. Courtenay graduated at Trinity College, Dublin, and entered the Indian Civil Service. For sixteen years he was occupied with this work in the district of Bombay, but finally was obliged to retire through ill-health. He never recovered, and was more or less of an invalid for the remainder of his life.

He married in 1878 a daughter of the late Mr. W. L. Holman of Murrie, India, who predeceased him. He leaves three sons and three daughters.

He was elected a Fellow of the Society 1906 February 9.

GEORGE HOWARD DARWIN, Knight Commander of the Bath, was born at Down, Kent, on 1845 July 9. He was the second son of Charles Robert Darwin (author of the *Origin of Species*), and of Emma Wedgwood, granddaughter of the well-known potter of Etruria in Staffordshire. His own work was to be in spirit analogous to that of his illustrious father; but it is not impossible that the influence of his schoolmaster, the Rev. Charles Pritchard, is to be seen in the actual direction taken by his researches. Pritchard, before he became Savilian Professor at Oxford, was for thirty years a schoolmaster in Clapham, and there he had for his pupils the sons of many men distinguished in scientific and professional life. The names of Airy, Hamilton, and Herschel are sufficient to suggest the class of family to which the school especially appealed. Pritchard was a pioneer in scientific education, but this did not involve any neglect of the basic subjects of education, and Darwin in due course gained a mathematical scholarship at Trinity College, Cambridge. He graduated as Second Wrangler in 1868, gained a Smith's Prize, and was elected a Fellow of Trinity in the same year. Lord Moulton was the Senior Wrangler of his year, and Sir William Christie was Fourth Wrangler in the same year. Darwin was called to the Bar in 1874, but he soon returned to Cambridge, and in 1875 began the series of mathematical papers the flow of which was only to cease with his death.

The recent publication of Darwin's *Scientific Papers* has rendered comparatively simple the task of describing the side of his life which they represent. He himself had undertaken the task of classifying and codifying his work. What is of interest here is to discover from the chronological table of his papers the

emergence of the germs of his subsequent work. In 1876 he produced the first of a long series of important discussions of the problems of geophysics. His paper "On the Influence of Geological Changes on the Earth's Axis of Rotation" was refereed for the Royal Society by Lord Kelvin. It was the occasion of bringing the two into an intimate relationship which had most important effects on the line of research subsequently adopted by Darwin. The series of papers on "Tides in a Viscous Spheroid," published in the years 1879, 1880, is to be largely attributed to the influence of Kelvin: this is made clear not only by the frequent reference to his name in these papers, but by Darwin's cordial acknowledgment of his debt to Kelvin in the prefaces to the first two volumes of his printed papers. But the development of the ideas was essentially Darwin's own. From cosmogony and theoretical tides in the solid earth his practical instinct passed to the problem of detecting and measuring these tides. Experimental conditions requisite for the elimination of the many disturbing factors in this delicate research were not available, and the researches of Darwin and his brother Horace on this point remained inconclusive. But their papers contain an important historical account of the subject which remains of great interest now that the problem has been largely solved by others. Pressure of other work prevented Darwin from returning to these experiments, for he was already becoming closely concerned with the important but arduous "Harmonic Analysis of Tidal Observations." This work was carried out by Darwin in conjunction with Lord Kelvin, Professor Adams and Major Baird serving as committees to the British Association. In the midst of this work came the death of Professor Challis of Cambridge. Though Darwin's work had not been along orthodox astronomical lines, the value of his original research was already recognised, and in 1883 he became Plumian Professor of Astronomy and Experimental Philosophy: he was re-elected to a Trinity Fellowship in 1884.

Darwin's fresh responsibilities were happily not allowed to check his output of original work, and he shortly began to break fresh ground in a new direction. The heavy numerical work which he had had to face in the Tidal Analysis may have been to some extent responsible for the fact that in his work on "Rotating Masses of Fluid," he steadily cast his theoretical writings in such a form that numerical results could be derived from them. This interest in actual values underlying theoretical conclusions had always been present, but his later work was to involve him in enormous labour cheerfully undertaken and to his own mind well justified by the interest of his results. Both in the theory of the "Figures of Equilibrium of Rotating Masses of Fluid" and in his "Periodic Orbits" Darwin was to make a straightforward frontal attack on problems which his compeer Poincaré was outflanking, so to speak, with brilliant, wide generalisations. As Darwin himself said in presenting the gold medal of this Society to Poincaré: "To one class of mind the easier process is the consideration of some simple

concrete case and the subsequent ascent to the more general aspect of the problem . . . [but Poincaré] finds it easier to consider first the wider issues, from whence to descend to the more special instances." Darwin's work places him clearly with the former class of thinker, but the combination of Darwin and Poincaré working at the same problem was most fruitful in results, and there is a sad fitness in the fact that obituary notices of both should be within the same binding of many a scientific journal. Before passing to a more detailed discussion of the results of Darwin's works which have a direct astronomical bearing, the fact should be again emphasised that it was the cosmical applications of his researches that inspired him in the prodigious labour which his later work involved. This part of his work is far from exhausted. His original purpose in discussing periodic orbits arose from a "desire to discover how a Laplacian ring could coalesce into a planet." A family of orbits which throws light on this problem was discovered by him only last year, and described in the *Monthly Notices* for June 1912. Other writers are still using and developing the ideas and methods which Darwin initiated.

The application of tidal friction to a wide range of cosmogonical problems led in Darwin's hands to a number of interesting and novel results, the most important of which will be stated in summary form below. The mathematical analysis required in the investigation was necessarily somewhat heavy and need not be discussed here, but reference must be made to the extremely illuminating graphical method developed by Darwin. By comparison of the equation of conservation of moment of momentum with the energy of the system for various configurations, he was able to trace for actual problems the direction in which individual elements would alter as the energy diminished by tidal friction.

The earliest of Darwin's papers which calls for detailed notice here is his paper "On the Precession of a Viscous Spheroid and on the Remote History of the Earth," published in 1879. Investigation showed that the period of diurnal rotation of the Earth, the obliquity of the ecliptic, and the Moon's distance were all in a state of flux under the influence of the action of the Moon and the Sun on the earth-tides. Looking backwards through the ages, we can see all three elements steadily decreasing. Under certain assumptions it was calculated that at some period, not less than fifty-four millions of years back, the Earth was rotating in about $5\frac{1}{2}$ hours and the Moon revolving about it in the same time. This was a condition of dynamical instability, and Darwin was led to the conclusion that it had arisen through the breaking up of one rotating mass of fluid into two. This view that the Moon originated by fission from the Earth has been the subject of much controversy. The later work on the figures of equilibrium of rotating fluids was undertaken largely for its bearing on the problem. Darwin discovered, simultaneously with Poincaré, that as the velocity of rotation of the fluid was increased a new type of equilibrium figure was found, the so-called pear-shaped figure. Carrying his

study of the question further, he reached a stage where the development of the pear into a kind of egg-glass form suggested that separation into two bodies was imminent; the tides lead backward to a similar crisis where two bodies appear close together in a very unstable and therefore transitional state. The further deduction that through some kind of gravitational instability, whose *modus operandi* defies the methods of exact analysis, the change indicated took place and a pear-shaped single body broke up into two, was made by Darwin; it does not seem that subsequent work ever led him to abandon the view, though he never insisted on it as a demonstrable fact. Darwin also traced the future development of the system in the way of a lengthening day and month and changing obliquity, but he pointed out other disturbing causes and refrained from making any numerical estimate of the present rate of tidal friction.

Darwin's next step was to make good the position which he had gained by introducing into his analysis some of the factors of the case which for the sake of mathematical simplicity he had omitted in his earlier work. In his paper "On the Secular Changes in the Elements of the Orbit of a Satellite revolving about a Tidally Distorted Planet" he took into consideration the effects of eccentricity and inclination in the orbit of the satellite. His more exact and detailed discussion of the problem led to an alteration in his estimate of the time of rotation of the Earth at about the period of instability; this he now placed at between 2 hours and 4 hours. The gradual opening out and tilting of the lunar orbit, also its distortion from a circular form, was followed out step by step to the present day. Applications to the other satellite systems known to us were made in a tentative manner. This application of the tides—so important in the evolution of the Earth-Moon system—to the other planets was made in a subsequent paper. The general conclusions to which Darwin came on this question were two. Firstly, that the relative smallness of the other satellites compared with their primaries would make tidal friction a much less efficient factor in modifying their orbits than in the case of the Moon; and secondly, that many data of our system, such as the progressive increase in the number of satellites as we recede from the Sun, are in accord with the suggestion that tidal friction has been an effective agent in the evolution of the inner planetary sub-systems at least.

To Sir George Darwin's other mathematical work brief reference only can be made. His practical bent was shown in his study of ripple-marks and thrusts in sand. In his treatment of Ellipsoidal Harmonic Analysis the claims of arithmetical work were borne in mind, with subsequent results in investigations of difficult problems of stability. His work on the "Theory of the Earth's Figure" contributed to his being the foremost English geodesist of his day. He bore the brunt of the practical application of Kelvin's analytical methods in the discussion of the Tides, and contributed articles on the Tides to the *Encyklopädie der mathematischen Wissenschaften*

(with the collaboration of Mr. S. S. Hough) and to the *Encyclopædia Britannica*. He also published a popular book on *Tides and Kindred Phenomena in the Solar System*, which has been translated into many languages and has run into several editions. This book arose from a course of lectures delivered at the Lowell Institute in Boston, and it leads naturally to a mention of the addresses which Darwin gave before the learned Societies of which at one time or another he was President. His address on "Cosmical Evolution," which he gave when President of the British Association in South Africa in 1905, gives a complete account of his later views on the evolution of the solar system and some suggestions in the wider field of the stellar universe.

Darwin in natural course came to hold many important scientific positions. Elected a Fellow of the Royal Society in 1879, he served on the Council for three terms and was a Vice-President for the year 1908-9. Due recognition of his work was shown by the Royal Medal, awarded in 1884, followed by the Society's highest honour, the Copley medal in 1911. As a member of the Meteorological Council and Solar Physics Committee he added to the valuable work which he did for the practical science of the state: his connection with the British Association has been referred to; he was President of Section A in 1886. He served on the Council of the Royal Astronomical Society in 1881-5 and 1895-1902; he was President in 1899-1900, when the gold medal of the Society was presented to Poincaré. He himself had received the medal eight years earlier. He was Vice-President of the International Geodetic Association, represented Great Britain at its gatherings, and was largely responsible for the success of the meeting in London and Cambridge in 1909. As President of the Cambridge Philosophical Society he welcomed the Fifth International Congress of Mathematicians to Cambridge in August last, and was elected President of the Congress. We cannot forbear to quote from his address of welcome to the Congress. It is perhaps his last published speech, and it reflects truly the modesty and honesty of the man. Speaking of the Problem of Three Bodies, he says:—

"My own work on the subject cannot be said to involve any such skill at all, unless indeed you describe as skill the procedure of a housebreaker who blows in a safe door with dynamite instead of picking the lock. It is thus by brute force that this tantalising problem has been compelled to give up some few of its secrets, and, great as has been the labour involved, I think it has been worth while. . . . To put at their lowest the claims of this clumsy method, which may almost excite the derision of the pure mathematician, it has served to throw light on the celebrated generalisations of Hill and Poincaré.

"I appeal, then, for mercy to the applied mathematician, and would ask you to consider in a kindly spirit the difficulties under which he labours. If our methods are often wanting in elegance and do but little to satisfy that æsthetic sense of which I spoke

before, yet they are *honest attempts to unravel the secrets of the universe in which we live.*"

In the words which we have put into italics lies the motto of Darwin's life. Lived simply as he lived it, with his ability and persistence it brought him necessarily honoured recognition from all parts of the world. Ten universities gave him their doctorate, twenty-five learned societies or academies elected him as a foreign or corresponding member. Berlin, Paris, Rome, St. Petersburg, Vienna, Washington all recognised his worth, and he served as by natural right on the International Association of Academies Committee of the Royal Society. Societies so diverse as the Royal Geographical Society and the Institution of Civil Engineers awarded him their medals.

One other aspect of Darwin's life calls for treatment here, his career as a professor of astronomy. Judged by the crude test of numbers, he would seem to have failed in this portion of his life-work. But this judgment would be wrong: it must be borne in mind that for advanced mathematical astronomy, with its small field of satisfactory careers, only a select few can be expected to find the necessary incentive to face the difficulty of the work. The names of a few of Darwin's pupils are sufficient to show the wide range of his influence and the stimulus that his teaching and personality have supplied: Professor Ernest Brown and Dr. Cowell have been awarded the gold medal of the Royal Astronomical Society; Mr. Hough and Mr. Jeans have amongst much other work made important additions to Darwin's own researches. Of great value to astronomy was the work that Darwin did for over twenty years as Secretary of the Board of Electors for the Isaac Newton Studentships. He followed carefully the work of the students, many of whom owed much to his friendly interest.

To Darwin is largely due the revival of the teaching of practical astronomy in Cambridge; Professor H. H. Turner was his first demonstrator; the Geographical School at Cambridge also owes much to the friendly support which Darwin gave steadily to the teaching of geography in the University. Darwin served for a while on the Council of the Senate and on the Financial Board of the University, and he also rendered valuable service from the start to the Appointments Board, a body which seeks to facilitate the placing of University graduates in many non-academic walks of life. But it cannot be said that in work on committees, concerned with the details of academic life and reform, he was most happily employed. To a great extent he was able to avoid the loss of time involved in such work, and to remain where he was far happier, in his study: there he was always to be found seated in an armchair, with a writing board in front of him and with papers covered with computations strewn all around. It was there that he lived his real professorial life, and there he was always ready to help the young student who sought his presence.

He married in 1884 Maud, daughter of Charles du Puy, of Philadelphia, U.S.A. He leaves behind him two sons and two

daughters. The eldest son, Charles G. Darwin, was Fourth Wrangler in 1909 and is now Reader in Mathematical Physics at the Victoria University, Manchester.

Sir George Darwin was elected a Fellow of the Society 1879 November 14. F. J. M. S.

JOHN FRANKLIN-ADAMS was born at Peckham on 1843 August 5. He was son of the late John Adams, of Lloyds, and was educated first at the Blackheath Proprietary School and afterwards at Berlin and Havre. This Continental education, combined with subsequent travels in Spain, Italy, Russia, and Scandinavia, gave him a considerable command of modern languages. He was one of those men who, like South, Lassell, De la Rue, and many others, find themselves drawn, by a species of natural compulsion, into the pursuit of practical astronomy.

It was not until comparatively late in life that Franklin-Adams' thoughts turned strongly towards astronomy; but when they did, and he came into contact with others interested in the subject, his imagination was fired, and he devoted a large share of his vigorous intellect and extraordinary energy to its pursuit.

In 1863 he began business at Lloyds, and finally became one of its senior members. He married in 1879 and took up residence at Chislehurst, where his five children were born. In 1890 he moved to Wimbledon, and there began the practice of astronomy, for which he had from his youth shown a certain liking.

His early education and the engrossing character of his business occupations had not prepared him for such work; but the writer can never forget the enthusiasm with which he described the satisfaction he found in working out the theory and practice of the use of a transit instrument both in the meridian and the prime vertical. He had no instructor beyond a book, his instruments, and his own wits, and he declared that no one could really learn practical astronomy unless he began in that way and worked out things for himself.

His first instrument was a 4-inch telescope, on a tripod stand, which he transferred to Machrihanish in Argyllshire, where he went from time to time for golf and recreation, and about 1897 he bought a house there to which he added an observatory. The 4-inch telescope was mounted on a stone pier; a 6-inch equatorial, a transit instrument with piers and bearings for use both in the meridian and prime vertical, and various clocks were afterwards added. He had been interested in photography from the time of the wet collodion plate, and it was at Machrihanish that he conceived the idea of making a complete photographic survey of the "Milky Way."

He afterwards extended this scheme to the photographic charting of the whole heavens from north to south, and finally procured an equatorial mounting by T. Cooke & Sons consisting of a well-designed double polar axis of the English type, driven by a Repsold clock, with which he began to take the necessary

photographs. This admirable mounting carried two triple photographic lenses by T. Cooke & Sons, of 6 inches and 10 inches diameter. A full description of these will be found in the *Monthly Notices* for May 1904.

In 1900 Franklin-Adams went with an observing party from the Royal Observatory, Edinburgh, under Professor Copeland, to Santa Pola, Spain, for the Total Solar Eclipse on May 28 of that year, which was successfully observed.

In 1902 Mr. Adams became very ill and was advised to make a journey to the Cape of Good Hope. He came there with the somewhat incongruous double purpose of curing the rheumatism and neuritis from which he suffered, and of photographing the southern heavens. He occupied rooms near the Royal Observatory during one half of each month, and during the other half of the month, when moonlight would fog his long-exposure plates, he went to the Sanatorium of Caledon, about 60 miles distant from the Observatory, where he took a course of baths from the celebrated hot chalybeate springs there. It was in vain that the doctor and his friends urged him first to complete his cure and then to do his astronomy—nothing would turn him from his purpose. He would come back from Caledon at the end of a fortnight greatly benefited, and undo a great part of that benefit by long exposure at night, to return as cheerily as ever to Caledon at the end of a fortnight. At first he could not dress without assistance or wash without difficulty and pain. His condition of health slowly improved, but his enthusiasm, optimism, and energy told against the permanent improvement of his health and the ultimate quality of his first series of Cape photographs. He had made a plan for doing his work which left no time for preliminary experiment, for his previous experience did not enable him to realise how numerous are the precautions, trials, and tests required to obtain perfect astronomical photographs with plates 15° square, taken with a telescope of 10 inches aperture and so short a focus as 45 inches.

The object-glass was a very fine one, the stand and clockwork practically perfect, but the mounting of the lens did not allow of its accurate centring and squaring, nor was the wooden tube capable of the necessary precise adjustment in permanent parallelism with the axis of the 10-inch lens. In spite of all advice he insisted that the work must go on before these things could be altered.

On his return to England in the spring of 1904, Mr. Franklin-Adams moved into a new house which he had built for himself at Mervel Hill, Hambledon, near Godalming, to which an observatory of suitable size was attached. Besides the admirable photographic equatorial by Cooke, already mentioned, the observatory contained an equatorial by T. Cooke & Sons of York, having a twin steel tube fitted with a 7-inch triple Taylor object glass and an excellent 8-inch object-glass by Wray, together with a 10° objective prism mounted in such a way that it could be available for use with either of the object-glasses; a meridian circle by Jones having an object-glass of 3½ inches aperture and 57 inches focal length; a

prime vertical transit by Troughton & Simms with an object-glass of $3\frac{1}{2}$ inches; various clocks, a chronograph, and meteorological instruments. Here photographs were taken similar to those at the Cape, but with exposures of 2 hours 20 minutes, the extra 20 minutes being necessary because of the difference in quality of the sky. Extensive preparations were made for measuring and counting the stars on these plates and the work was begun, but not finished, by Mr. Franklin-Adams.

In 1905 he went with Professor Becker of Glasgow to Algiers to observe the eclipse of August 30, his son Bernard accompanying him, and on his return, the work of completing the negatives of the northern hemisphere and of making positives from them was pushed on with much vigour at Mervel Hill, as may be seen from the Reports in the February numbers of the *Monthly Notices* in 1908, 1909, and 1910. An apparatus for ruling meridians on these plates, preparatory to counting the stars, was made, and some experimental work of this kind was done. This apparatus and specimens of the photographs were exhibited at the *Conversazioni* of the Royal Society in various years. Difficulties were found, from dew-formation on the surfaces of the object glass of the telescope, which were overcome by an ingenious method described by Mr. Franklin-Adams in notes in the *Monthly Notices*, vols. lxx. p. 543, lxxii. p. 165. Eventually the plates taken at Mervel Hill were found to be superior to those taken at the Cape in 1903-1904, and it was decided to repeat those of the southern hemisphere. Mr. Franklin-Adams was preparing to go to South Africa in November 1909, but a recurrence of his illness which had been threatening spoiled his plans, and the 10-inch equatorial was sent to the Observatory at Johannesburg in charge of his assistant, Mr. Mitchell. The telescope was used to photograph Halley's Comet in 1910, excellent pictures being secured: it has since been used to repeat plates of the southern hemisphere, the series having been completed by Mr. Innes, but Mr. Franklin-Adams was never able to use the telescope again. His illness increased, and he had to give up his observatory and his astronomy in 1910. In the next year he retired from business at Lloyds. The 10-inch equatorial was presented to the Transvaal (now the Union) Observatory, the 6-inch lens has been lent to the Royal Observatory, Greenwich, and the photographs and micrometer designed by Mr. Franklin-Adams were handed into the charge of the Astronomer Royal. The work of counting the stars on these plates has been in progress at Greenwich for the past two years. Before his death Mr. Franklin-Adams also presented the Cooke twin equatorial to the Union Observatory. The appreciation of such men as Kapteyn, Dyson, and others interested in cosmical astronomy was to Franklin-Adams an immense satisfaction in his latter days, and it is sad to think that he did not live to see the full outcome of the work, for which he had made so many sacrifices.

Mr. Franklin-Adams was a keen musician. In early life he acted as organist and choirmaster at All Saints' Church, Putney,

in the building of which he was largely instrumental. He had been an active volunteer, taking part in many shooting competitions at Wimbledon, and went with a volunteer ambulance to the Franco-German War in 1870-71. He was a golfer and a Freemason, holding high office in the Craft, and was twice Master of the Armourers' and Braziers' Company. He died at Enfield on August 13 last, at the age of 69, leaving a widow, two sons, and three daughters, and his ashes, after cremation, were buried there on 1912 August 16.

He was elected a Fellow of the Society 1897 April 9.

D. G.

ARTHUR ERNEST HODGSON was born at Leeds in 1880. The greater part of his scientific education was obtained at the Royal College of Science, London, which he entered as a teacher in training. After passing through this course he became a demonstrator in the Astrophysics division, and in June 1902 was appointed computer in the Solar Physics Observatory.

He resigned this position in April 1903, on his appointment as Junior Astronomical Assistant at the Natal Observatory, Durban, where he commenced duty on 1903 May 12. At Durban he was placed in charge of the time-service observations, involving routine clock-star observations and reductions, comparison of clocks and chronometers, etc., and he also took part in the meteorological routine work and general astronomical night observations. During the year 1907 he secured a series of observations of Comet 1907 *d* with the large equatorial, and in 1908 he made a new series of lunar photographs for a determination of the physical libration of the Moon. After the retirement of the senior assistant, Mr. Hodgson was appointed to that position in 1910, and it was anticipated that he would have been placed in sole charge of the Observatory on the retirement of the Government Astronomer, Mr. Nevill.

He was a very earnest and enthusiastic worker, and interested himself in various branches of science having bearings on the subject of astrophysics, which he had adopted as a profession. All who worked with him have pleasant recollections of his companionableness and friendship, and from notices in the Natal press it is evident that the same feeling was entertained for him in his adopted home.

His death occurred at Durban on 1912 February 11.

He was elected a Fellow of the Royal Astronomical Society 1903 November 13, and was a member of the Physical Society.

C. P. B.

ISAAC MOLLOY was born at Rathfarnham, Dublin, in October 1846. He was educated at Trinity College, Dublin, where he graduated in 1868, and afterwards in Germany. Adopting the legal profession, in which his family name had become well known, he was admitted solicitor in 1871. Four years later he joined his

brother in founding the firm of Messrs. Molloy & Molloy, solicitors, 18 Eustace Street, Dublin, of which he was afterwards sole principal. He enjoyed a high reputation as an able lawyer, being solicitor to many important firms. He was an active politician, and twice unsuccessfully contested South Dublin in the Unionist interest.

In his leisure hours he took an enthusiastic interest in astronomy; he was also a keen student of Egyptology and other antiquarian studies. He was a member of the Royal Dublin Society.

He died at Rathmines on 1912 March 10.

He was elected a Fellow of the Society 1905 March 10.

RICHARD MUNDAY was born at Deal on 1826 December 18. He was educated in France, and entered the Royal Navy as Assistant Clerk in 1843. He served as Assistant Paymaster on H.M.S. *Duke of Wellington* in the Baltic in 1855 and received a medal and clasp for his services at the bombardment of Sveaborg. It was whilst at Malta, acting as Secretary to Admiral Sir H. Codrington, 1860 to 1863, that he made astronomy the subject of especial and continuous study; but his interest in the science was lifelong. In 1869 he was selected to serve as Secretary to the First Lord of the Admiralty, Right Hon. H. E. Childers, during a two months' cruise of inspection in that year. He retired from the navy with the rank of Paymaster-in-Chief in 1882, and took up his residence in Plymouth, where he spent the remainder of his long life. He was an active member of many public philanthropic institutions in the town.

He married in 1864 Susan Elizabeth Meadwell, who survives him. He leaves three sons and a daughter. His death took place at Plymouth, 1911 December 28.

He was elected a Fellow of the Society 1863 January 9.

WALTER A. POST was born at Kingston, New York, in 1857 January. Both his father and mother were of English descent. He was educated in New York, and followed the profession of civil engineer in the United States. In 1890 he became associated with the Newport News Shipbuilding and Dry Dock Company, of which he was made General Manager in 1898 and President in 1911. Under his management the Company made great advances, and many of the highest type of battleships of the United States Navy have been constructed in its yards.

Mr. Post took a keen interest in astronomy, and built for himself a private observatory. His equipment included an equatorial with a six-inch Brashear lens.

He married Miss Ada F. White of New York City in 1878. His death occurred suddenly on 1912 February 12.

He was elected a Fellow of this Society 1894 March 9.

SAMUEL ARTHUR SAUNDER was born in London on 1852 May 18, the son of William Deacle Saunder, dental surgeon, and Sarah Patience, eldest daughter of Thomas Nokes, Esq., of Stifford Clays,

Essex. His father was the son of Samuel Saunder, surgeon, of Charlbury, Oxon., and was twice married. Of the first marriage there was one son: of the second two daughters, one of whom died in infancy, and one other son in addition to the subject of this notice. The various members of the family all showed a moderate interest in science, but perhaps a stronger preference for the arts. Samuel Saunder was educated like a true Londoner at St. Paul's School (which has the distinction of claiming Halley), and showed such exceptional ability as to proceed to Trinity College, Cambridge, with an adequate scholarship. He graduated as fourteenth wrangler in 1875, but the place does not represent his merits, since he was attacked by illness during the examination and had to leave one paper untouched. (The place forecast for him was among the first three, who were Lord, Burnside, and Chrystal.) In 1876 he became an assistant master at Wellington College, and so remained until a few months before his death, when he had been senior mathematical master for thirty years. He married in 1888 August 16, Alice, third (and eldest living) daughter of the Rev. William Duthoit, D.C.L., of Crowthorne, Berks. The eldest of three children, a girl, died in infancy; and the mother died eight days after the birth of the second son, on 1893 August 21. The two sons are now at Cambridge.

Saunder was a man of many interests and a hard worker at them all. To his regular school duties he added the care of the Scientific Society, which included the arrangement of lectures, many of which he gave himself, and the working of the lantern. He also started the school "tuck-shop," and managed it with great business ability so as to subsidise other school enterprises. He had been a successful oarsman at Cambridge, winning the Colquhoun sculls in 1875; and in after years he did much canoeing on the canals of England. He was also a keen and expert fisherman. But all other interests gradually became subordinated (when they did not entirely disappear) to his love of astronomy in all its aspects. He purchased a fine 7-inch refractor by Troughton & Simms and set it up near his house in a shed with sliding roof which he designed himself, and which has since many times served as a pattern of a modest but thoroughly useful telescope house. He put the telescope to a variety of uses. He had a spectroscope for it, and a first-rate micrometer: he showed how he could use it as a transit instrument for getting time (*B.A.A. Journal*, vol. v. p. 461): and once he found a comet, only to meet with the mortification of finding that it had been previously discovered. But he gradually settled down to observation of the Moon, and became desirous of improving the accuracy of our selenographical knowledge. His first paper to our Society, of which he was elected a Fellow in November 1894, was on "The Determination of Selenographic Positions and the Measurement of Lunar Photographs" (*Mon. Not.*, lx. 174). It called attention to the uncertainty of the known positions, often over 5", and to the probable cause in the use of the limb as an origin

of reference. He proposed to abolish the limb for this purpose and use the crater Mösting A as origin: and he has successfully proved his point by attaining an accuracy of $0''.1$, some fifty times better than that in existence before he began work, for over 3000 positions of objects on the Moon's surface.

This result was naturally not achieved without much work and many disappointments. The method first tried, which involved using existing knowledge as a basis, broke down altogether. The places were too rough to give even a start. Then he devised a very ingenious method of measuring two plates with different librations, using the stereoscopic displacement as a base: but the base was not long enough, and this method would not do. It was apparently necessary to measure at the telescope the distances of several fundamental points from Mösting A, and this work Saunder undertook himself, though he was much helped by Professor Barnard's measures of two points. It is pleasant to remember that this timely help was the outcome of one of our Society's meetings: Professor Barnard happened to be present when Mr. Saunder was explaining his difficulties, and next day volunteered the help needed (*Mon. Not.*, lx. p. 540). This third attempt, starting from measures at the telescope as a basis, was completely successful, and led to the Catalogue of over 3000 selenographical positions in *Mem. R.A.S.*, vol. lvii. From comparisons of different plates a number of heights of lunar mountains was also obtained; but this work was little more than commenced when death cut it short.

Saunder had gradually become an authority on the Moon, and had learnt all that was to be known from former observations. His attention was incidentally attracted to the unsatisfactory state of lunar nomenclature, many cases occurring where the same object had different names, or different objects the same name. An authoritative standard nomenclature must clearly be international in character, and he appealed, through first our own Society, and then the Royal Society, to the International Association of Academies, at its Vienna meeting in 1907. A committee was at once appointed to deal with the matter, and Saunder and Franz, who had both done so much for the accurate measurement of the Moon, were naturally nominated as members. After some discussion of preliminaries, these two gentlemen were asked by the chairman (M. Loewy) to undertake the formation of an accurate map of the Moon as a vehicle for the standard names. We have to deplore the loss of both these eminent workers within a few weeks of one another. Saunder had, however, completed his own work on the map: he had laid down for Mr. Wesley the standard points on all four of the portions of the map which fell to his share: and three of these have been completely drawn by Mr. Wesley, and reproduced, the drawing of the fourth being also commenced.

To this work on lunar nomenclature, and to the heights of lunar mountains, Saunder was hoping to devote himself in the immediate future. Some years ago the advent of a new head-

master to Wellington College brought also the unwelcome surprise of compulsory retirement, without pension, at sixty. For this unkind stroke of fate Saunder found some compensation in the fact that he would be able to work with more leisure at the Moon.

He reached the retiring age during the past year, and his teaching duties came to an end with July 1912. After some consideration he arranged to settle at Oxford, finding a house with a garden suitable for his telescope and not too far from the University Observatory. But after the lease had been signed, and while he was planning the building for his telescope, he became ill, and it soon became clear that the trouble was possibly serious, though exact diagnosis was difficult. Later the gravest of the alternatives declared itself. On November 29 he learnt something of the possibilities, and his first thought was to ask the present writer whether he could spare a few hours to discuss plans for carrying on the lunar nomenclature work. The following day was spent in this discussion, so long as his strength permitted, and was the last on which he was capable of the mental strain. He died peacefully on December 8, a few days before the meeting at which it had been hoped to nominate him President of the Society.

Saunder was devoted to work of all kinds. He was an original member of the British Astronomical Association; was a constant attendant at its meetings, in spite of the troublesome journeys that were involved; and was President 1902-1904. His two Presidential Addresses, devoted to the history and present state of selenography, condense a vast amount of research into a few very readable pages. He had rare skill as an expositor, and when elected Gresham Professor of Astronomy in 1909, delivered courses of admirable lectures which must have cost long hours of his scanty leisure. The last series of four was given under conditions such as few lecturers have ever faced: illness came suddenly upon him in a way which made it a severe pain to speak at all loudly: but he heroically declined all offers of help except that which a masseur could give him immediately before each lecture, and it is probable that the audiences never suspected what torture their lecturer was undergoing. He went straight from the last lecture to the bed from which he was never destined to rise.

Saunder was Secretary of our Society from 1906 to 1912, and it may safely be said that no Secretary ever worked more devotedly for the Society during his term of office.

He was elected a Fellow of the Society 1894 November 9.

H. H. T.

LEWIS SWIFT was born at Clarkson in the State of New York on 1820 February 29. Of his parentage and education but little information is obtainable. Apparently his life for many years was spent in commercial business, as about 1856, when he first devoted himself to astronomy, he was engaged in the hardware trade, in which he continued up to about the year 1882.

In his own account of the "ups and downs and here and there

of an astronomer," he has described his early difficulties and misfortunes in the pursuit of astronomy. He commenced with a 3-inch object-glass, for which he made a tube and an eyepiece; but the object-glass was shortly after broken by the carelessness of a servant. He then obtained a $4\frac{1}{2}$ -inch comet seeker, which he used with excellent results at his then residence at Marathon. With this instrument he discovered on 1862 July 15 the first of the series of thirteen comets which he independently discovered. This comet was 1862 III., and is memorable on account of its orbit being identical with that of the August meteors. The following is the list of comets discovered by this assiduous observer—

1862 III.	1881 II.	1892 I.
1877 III.	1881 VIII.	1895 II.
1878 I.	1883 I.	1896 III.
1879 II.	1889 VI.	1899 I.
1880 IV.		

Swift's struggles in the pursuit of astronomy were subject to several misfortunes and difficulties. On one occasion, in moving the telescope, he stumbled and fell with it to the ground, seriously injuring the tube. On another day, while removing the dew-cap, he detached the objective which, falling on some stones, smashed the flint lens to atoms. In these days the only place he had for observing was on the flat roof of a cider mill, half a mile from his residence. To get on to this roof it was necessary to climb three ladders and to walk some 100 feet on a slanting roof, which in the early morning hours was often covered with frost, necessitating walking on hands and knees.

About 1882, when he was living at Rochester, Swift was introduced to Mr. H. H. Warner, who greatly befriended him, and who told him that if the people of Rochester would buy him a 16-inch telescope he would build a nice observatory and a dwelling attached. Eventually 12,500 dollars were subscribed; the observatory and residence were built by Mr. Warner, and thus Swift became Director of the Warner Observatory. While here he made many of his cometary discoveries as well as discovering 900 nebulae. He remained in this position for some years until Mr. Warner failed, which brought serious trouble to Swift. About this time Professor T. S. C. Lowe was constructing an observatory on the San Gabriel Mountains in California, about 3700 feet above sea-level, and as soon as it was completed he made Swift its director. At this observatory he discovered two more comets and 340 nebulae, and there he remained for some years; but his misfortunes were not over, for Professor Lowe also failed, and Swift's work was brought to an end, and, moreover, his sight became affected.

Swift made very valuable contributions to astronomy under great difficulties, and it was in recognition of his good work and in sympathy with his trials and misfortunes that the Royal Astronomical Society in the year 1897 awarded him the Jackson-Gwilt medal and gift.

No notice of Swift's astronomical work would be complete without reference to his supposed discovery of an intra-mercurial planet.

On the occasion of the Total Solar Eclipse of 1878 July 29 observers were instructed to make a systematic search for an intra-mercurial planet. Swift was stationed at Denver, Colorado. He employed a $4\frac{1}{2}$ -inch refractor mounted equatorially but without circles. The aperture was reduced to $2\frac{1}{4}$ inches, and a comet eyepiece with a power of 25 was used; a little accident at the critical moment of totality hampered him in searching for the planet, and he was able to sweep only towards the west and south-west of the Sun. He came upon two stars south-west of the Sun, each having a round red disk and free from twinkling. His conclusion was: "that one was θ Cancri is in the highest degree probable, and the other a planet is beyond all question, for on the morning of September 10 I observed θ robbed of the companion I saw during the eclipsed Sun." Having no circles, the positions could only be estimated. Curiously, Professor Watson, who was observing at Separation, some 150 miles distant from Swift, also noticed, south-west of the Sun, two ruddy stars. His telescope was equatorially mounted, but also without circles, but he had fixed some temporary wooden circles and was thus able to estimate better the positions of the two objects. It was eventually found that there was considerable difference in Right Ascension between the objects supposed to be planets by the two observers. It was at once announced to the world that an intra-mercurial planet had been discovered, but no confirmation whatever of the existence of such a body has ever been made, and the only conclusion to be drawn is that the strange objects were possibly comets.

Dr. Lewis Swift received many honours for his discoveries. He was awarded the Lalande prize of the French Academy in 1881; from the Vienna Academy he received three medals; from the Astronomical Society of the Pacific, three medals; and, as already mentioned, he was the first recipient of the Jackson-Gwilt medal and gift of the Royal Astronomical Society.

He was a member of the British Astronomical Association.

Dr. Swift died on 1913 January 4, at the age of 92 years.

He was elected a Fellow of this Society 1879 April 9.

F. B. K.

LEWIS BOSS was born at Providence, R.I., on 1846 October 26, the son of Samuel P. and Lucinda (Joslin) Boss. There are no recorded traces of scientific tastes among his older relatives, nor among his thirteen sisters and brothers: but in his case such tastes manifested themselves early in his undergraduate life at Dartmouth College, where he had the good fortune to come under the genial influence of Professor C. A. Young. He paid frequent visits to the College observatory, and on his own initiative undertook a survey of the College grounds. The resulting map long served as an ideal of attainment for students who came after, though the name of the surveyor was soon forgotten.

He graduated in 1870. As no scientific opening presented itself, he took a post in the Government Census Office at Washington, which was soon changed for that of Examiner of Surveys in the Land Office. He haunted the U.S. Naval Observatory, and made good use of a sextant and chronometer lent him. When in 1872 the U.S. Northern Boundary Commission undertook the survey of the 49th parallel of latitude (between the U.S. and Canada), application was made to the Naval Observatory for a civilian astronomer. The staff of the Observatory recommended the young amateur who had been so busy with his sextant: and the sight of his neatly kept observations, combined with their excellent response to tests for accuracy, promptly decided Major Twining to appoint him.

Meanwhile, on 1871 December 30, Dr. Boss had married Miss Helen M. Hutchinson of Washington, who thus had the trying experience of being almost immediately separated from her husband for a large part of several years, and the added anxiety of following him in imagination through Indian territory, at a time of much Indian unrest. Fortunately, in spite of several threatening situations, there were no serious developments: the roughness of the virgin country proved a greater annoyance than the Indians.

Early in this enterprise Boss became dissatisfied with the declinations of the standard stars, and concluded that they could be amended with advantage. There are few men who would not have thought it reasonable, and perhaps even desirable, to defer this work until the field-work was completed: but it was characteristic of Boss that he set about it there and then, in the evening in camp after a hard day's surveying, when the other members of the expedition were taking their well-earned ease. By the close of the expedition in 1876 he was approaching the end of the work, and he was enabled to complete it by the offer of the Trustees of the Dudley Observatory, Albany, N.Y., to appoint him Director, a post which he eagerly seized and retained to the end of his life. But the continuous strain of the work led to an attack of vertigo during the last stages of the preparation of the catalogue, and his long-suffering eyes refused to work further. Nothing daunted, he enlisted the services of his devoted wife, dictating the introduction to her and amending the manuscript as she read it to him.

The catalogue of standard declinations was published in 1878 as Appendix H to the Report of the U.S. Boundary Commission. It contains an exhaustive discussion of nearly 100 fundamental catalogues, tables for the systematic correction of them all, and a final catalogue of the declinations and proper motions of 500 stars for the epoch 1875, which were at once adopted in the American Ephemeris. Of this Catalogue Newcomb wrote:—

“The declinations were so thoroughly worked up by Boss that the continued use of the A.G. system of declinations until 1900 is to be regarded as unfortunate.”

The catalogue finished, Boss undertook the observation of the Ast. Ges. zone $+0^{\circ} 50'$ to $+5^{\circ} 10'$. This zone was originally

assigned elsewhere and not taken up, so that Boss started late : but he finished early, the catalogue being completed in 1886, and presented for publication (the first to be so presented) in 1887 ; (that it did not appear till 1890 was due to slowness in printing).

It is scarcely necessary to consider Professor Boss's work here in great detail, since a full account of it was laid before the Society only eight years ago (February 1905), on the occasion of the award to him of the Society's Gold Medal. But it may be recalled that in making this zone catalogue he was not content with the differential programme laid down, but made two laborious determinations of division error and flexure of two circles used ; investigated his magnitude equation by using gauze screens ; and compared his catalogue with all others available, thus deducing a valuable series of proper motions and the motion of the Sun in space.

In 1878 he joined the U.S. Government Expedition to observe the total solar eclipse at West Las Animas, Col. In 1879 he began the observations of comets and computations of orbits. For several years the Dudley Observatory was the chief source of orbits of new comets. In 1881 he wrote a prize essay on the Physical Nature of Comets. In 1882 he took charge of the Government Expedition to Santiago di Chile for observation of the Transit of Venus. After the zone catalogue was completed he undertook as a relaxation the editing of a daily newspaper, the *Albany Morning Express*, and considerably improved its status. He also took an active part in politics for a time.

Meanwhile, he was maturing plans for his great work on proper motions ; and in 1889 he published some preliminary work on the subject which was to engross the rest of his life. But first it was necessary to move the Dudley Observatory to a better site, and this was accomplished in 1893 by the generous help, firstly, of Miss C. W. Bruce of New York, who gave £7000 in all ; and secondly, by the cordial support of the citizens of Albany. By 1896 the new observatory was ready to prepare a catalogue of 11,000 stars in the zone -23° to -37° , with special attention to stars with large proper motions. This catalogue was completed about 1903, but has not yet been published, owing to lack of funds.

After its completion the transit circle stood idle for a few years, in order that attention might be concentrated on the collation of catalogues, which had gradually become the important work of the Observatory. The method adopted was to deal in the first instance with those stars which had been observed everywhere or almost everywhere, thus affording a direct comparison of all the systematic errors. Boss found 627 of these Principal Standard Stars, and the results of an exhaustive study of their places and proper motions were published in the *Astronomical Journal* in 1903. Moreover, the catalogue, important as it was in itself, was not the only important outcome of the work, which included a discussion of the solar motion and precession. Using these 627 stars as a firm

foundation, Boss next discussed the places of 6000 stars, as a stepping-stone to his great scheme for 26,000 stars. About this time the Carnegie Institution came to his aid and gave him the computing help of which he had been in sore need ; so that for the last ten years of his life he had almost more work to look after than he could well manage. This was especially the case when his long-cherished desire to transport his transit circle to the southern hemisphere was carried into effect in 1909, for the observers of the expedition worked with such energy as to send back to Boss at Albany an almost overwhelming mass of observations, carrying out the programme in about half the expected time. The reduction of these southern observations, and the production of the large catalogue of 26,000 stars, is left as a legacy to his son, who has shown a devotion to this work not less than that of his father: but the father lived to see published his "Preliminary General Catalogue of 6188 stars,"—their places and proper motions.

As this catalogue was nearing completion, Boss wrote a remarkable paper "On the Convergent of a Moving Cluster in Taurus" (*A.J.*, No. 604), showing that a number of stars, separated from one another by distances of the order of thirty light-years, are nevertheless associated in a common movement. Already this discovery has borne fruit in the identification of other clusters of the same type: but it is safe to say that the full value of the new departure cannot yet be foreseen.

There followed a series of papers containing a more general study of proper motions and the deduced solar motion, particular attention being paid to the effect of spectral type. Ultimately Boss was able to confirm Campbell's discovery that a star's linear motion is a function of its apparent age: and another important generalisation is that the linear velocity of stars of type A rapidly increases with the distance of the star from the galaxy. For some time he was curiously adverse to the "two star-stream" hypothesis; but on a more careful scrutiny of his own material he found good reason to change his opinion. Had it not been for the distraction of the numerous observations from San Luis interrupting the examination of his proper motions, which he had already commenced, he would probably have arrived at this conclusion much earlier.

As regards the great project of transporting the Dudley meridian circle to San Luis, Boss had taken the view that since the instrument had been conveyed along a jolty road at Albany (from the old Dudley Observatory to the new) without upsetting its division errors, it could be conveyed sensibly intact to the southern hemisphere; thus securing the obvious advantages of a comparison of north and south star places determined with the same instrument. His prediction when thus tested was triumphantly fulfilled: and there is no doubt of the excellence of the observations or of their value for the great catalogue. He accompanied the instrument to San Luis and saw it set up: but he then left it in the able hands of Professor Tucker and returned to Albany. It was a considerable

enterprise for a man of his years in any case, and became very much more serious from the misfortune of shipwreck on the return journey. The boat struck on a rock at full speed, so hard and fast that she was impaled. The gravest danger was, indeed, lest she should wash off and fill with startling suddenness: but she held until the passengers were all got off in the boats. The coast was, however, too forbidding for landing in the dark, and the night was spent in the boats, under pouring rain. The next day allowed of landing on a desolate seashore, where twenty-four hours were spent, with very little food, until a steamer brought them off in considerable discomfort. All this was a trying experience to a not very strong man somewhat advanced in years: but it seemed, curiously enough, to have an almost stimulating effect. "I had several fatal diseases," Boss would say jokingly, "and now they have disappeared." But the disappearance of some of them was unfortunately not permanent. Whether the shipwreck really did more harm than he thought, or whether the great strain of his work, in which he never spared himself, was alone responsible, it is not possible to say; but about two years ago his condition became much more serious, and a larger and larger share of the work was handed over to his son. He died peacefully on 1912 October 5.

He was elected an Associate of this Society 1890 December 12, and received our Gold Medal in 1905. The Lalande Prize of the Paris Academy was awarded to him in 1911. He was a member of numerous learned societies, and received many honours. He leaves a widow, three daughters, and a son who is worthily carrying on his father's work. To him the writer is indebted for much information included in the present notice. H. H. T.

JULES HENRI POINCARÉ was born at Nancy on 1854 April 29. His father, who came of a Lorraine family, was an eminent physician; the President of France, M. Raymond Poincaré, was his cousin; and another cousin, M. Lucien Poincaré, is a distinguished physicist. As a boy he suffered from poor health, and doubtless it was partly owing to this that he acquired those habits of preoccupation and inward concentration of thought, which were characteristic of him afterwards. He was educated successively at school at Nancy, at the École Polytechnique, and at the École Supérieure des Mines. At the age of twenty-five he received the degree of Doctor in the University of Paris, and about the same time was appointed Professor of Analysis at Caen. The wide variety of his scientific investigations is reflected in the diverse professorships which at one time and another he held. At Paris University he filled successively the chairs of Mechanical Physics, Mathematical Physics, Calculus of Probability, and finally, for the last sixteen years, Celestial Mechanics; and at the École Polytechnique he was lecturer in Analysis and afterwards Professor of Astronomy. Yet one best-known branch of his activity is not represented in these. M. Darboux wrote to him: "Why does not the Faculty possess a chair of Scientific Philosophy? I should

have been able to ask you to occupy it also." To the general public in his country he first became celebrated by winning the international prize offered by King Oscar II. of Sweden in 1887 for a memoir on the Problem of Three Bodies; the award was received in France with great enthusiasm, and the prize essay, which was the foundation of Poincaré's *Les Méthodes Nouvelles de la Mécanique Céleste*, remains one of his greatest achievements. It is impossible to enumerate the honours bestowed on him in his own country and abroad; thirty-two academies received him as an associate. We may mention, however, that he received the Sylvester medal of the Royal Society, and the gold medal of this Society was awarded to him in 1900. He was received into the French Academy in 1909.

Whilst continually engaged in the most profound researches, and given to fits of abstraction and absent-mindedness, he nevertheless took an active part in all those administrative and consultative duties which are pressed upon an eminent man of science. As a professor he was a conscientious teacher. Of extraneous offices, he was President of the Conseil des Observatoires and of the Société Astronomique de France; in 1906 he was President of the Académie des Sciences; he was also a member of the Bureau des Longitudes. When presiding at official meetings he could throw aside his preoccupied habits and conduct the business with alert attention. With all the pressure of professorial and other work, the output of his scientific papers averaged one a week for the thirty-three years of his active career.

It is perhaps pardonable to claim M. Poincaré as pre-eminently an astronomer, though few men have the encyclopædic knowledge necessary to compare the merits of his contributions to pure mathematics, to mathematical physics, to astronomy, and to philosophy. Each of these studies owes a great debt to his genius. His was one of those rare minds that recognise no limits between the sciences; and we can dimly perceive how much of his success may have been due to the ease with which he could apply the weapons of one branch to the problems of another. His marvellous faculty of generalisation demanded an unrestricted field, and it was backed by an activity of brain which enabled him to enter deeply into so many diverse lines of knowledge. The problems of astronomy, of the evolution of the solar system and of the universe, appear, however, to have been his first interest; and in the last fifteen years of his life, by the professorial chairs he occupied, and by his presidency of astronomical societies and committees, he seems to have recognised it as the chief claim. His contributions to astronomy are so numerous that it is impossible to attempt a general survey of them. His last published work, a critical examination of the various cosmogonic hypotheses, represents one line of his investigations. An important paper on the problem of Saturn's ring may be mentioned. The modern theory of tides owes much to Poincaré. There are, however, two

special investigations, which by common consent are regarded as his chief title to fame, and these we may here consider especially.

In *Les Methodes Nouvelles de la Mécanique Céleste*, a great work in three volumes published between 1892 and 1899, the brilliancy and originality of his powers are most highly manifested. Sir George Darwin describes it as "the mine from which, for more than half a century to come, humbler investigators will excavate their materials." Professor Moulton, speaking of the mathematical processes employed, says: "In power and elegance they are as much beyond those of Laplace, as his were beyond the geometry of Newton." One of Poincaré's theorems showed that the series used in celestial mechanics are ultimately divergent for large values of the time. The various periodic terms in the motions of the planets, which suffice for ordinary discussions, hold approximately true; but no conclusion as to the ultimate stability of the solar system can be drawn, for the applications of the series are not valid beyond certain limits of time. This possible instability (for the conclusion is merely negative, and does not decide between stability and instability) must not be confused with that arising from the dissipative forces of the tides, to which Poincaré also devoted researches. The result we are now considering arises from the historic Problem of Three Bodies in its simple form.

From the discovery of the divergence or non-periodicity of planetary orbits, Poincaré was led to the consideration of theoretical orbits which are strictly periodic and therefore valid for all time. The subject of Periodic Orbits, which has now an extensive literature, is one with which the practical astronomer finds it difficult to feel much sympathy; he is inclined to condemn the whole matter as misguided ingenuity, or as pure mathematics in a thin disguise. But this attitude is not a just one. The subject originally arose in the study of the lunar theory, and G. W. Hill's fertile method depends on the "variational curve," which is the first example of a periodic orbit. To some investigators (and notably to E. W. Brown) the interest of these orbits lies in their application to the stability and possible distribution of the outer satellites of the planets. To Sir George Darwin it was a conviction that their study would ultimately afford a clue to the empirical law of Bode as to the distances of planets from the Sun. To Poincaré it was the one method by which it seemed possible to penetrate into the far-distant future of the solar system; or, to use his metaphor, "they furnish the only breach by which we may hope to penetrate the fortress of a problem hitherto deemed impregnable." Just as, although the Moon does not move along the variational curve, yet its deviation from this periodic orbit is always comparatively small, Poincaré believed that a similar use of periodic orbits might be made in determining expressions for the motions of planets valid for all time, for he showed that a periodic solution can always be found which shall differ by as small a quantity as we please from any given motion of the perturbed body.

Perhaps the researches which have aroused the widest attention are those in which Poincaré considered the possible forms of equilibrium of rotating masses of liquid, resulting in his discovery of the so-called pear-shaped figure of equilibrium. The possibility that in this way may be traced the first stages in the separation of a satellite from its primary, or the evolution of a double star, renders this work of great interest to all those who have speculated on the origin of celestial systems. But the real beauty of the investigation, and the far-reaching general principles which it contains, are often lost sight of through attention being focussed on the immediate practical result. As in the study of the Problem of Three Bodies, it was a question of stability which guided Poincaré's researches, and his results in the first instance apply with perfect generality to any mechanical system. He found that, where there is more than one form of equilibrium possible, if these forms are arranged in families, an interchange of stability and instability takes place between two families wherever they cross. If a stable and an unstable family converge, so that one limiting form may be considered a member common to both families, then on tracing the forms beyond this point, what was formerly the stable family becomes unstable, and *vice versa*. In the application to rotating fluid masses, it was known that when the ordinary oblate spheroid becomes unstable, the Jacobi ellipsoid with three unequal axes supersedes it as the stable configuration. Poincaré found that a point was reached when this also became unstable, and he argued that this must be a point where a new series of figures of equilibrium branches off. He investigated these new figures and showed their pear-shaped character.

In pure mathematics one of his most fertile generalisations was the invention of automorphic or, as he named them, Fuchsian functions. These functions are arrived at by an extension of the ideas of the theory of elliptic functions. The essential character of the elliptic function is its double periodicity, so that it is unchanged by a certain doubly infinite series of substitutions, just as $\sin z$ is unchanged by the singly infinite series of substitutions $z + 2n\pi$ for z . The Fuchsian functions have the property of being unchanged by a still more general series of substitutions, namely, of the form $(az + b)/(cz + d)$, subject to the condition $ad - bc = 1$. Poincaré was able to form zeta- and theta-Fuchsian functions corresponding to the zeta- and theta-elliptic functions. From this he was led to the discovery that the new functions sufficed for the integration of any linear differential equation with algebraic coefficients. They further enable the allied problem of expressing the co-ordinates of an algebraic curve in terms of a parameter to be solved in all cases.

In the modern developments of physics Poincaré was in the front rank of workers. A monumental work on the diffraction of electric waves is remarkable alike for the novelty of the analytical methods and the practical importance of the results. In his later years the principle of relativity and the allied problems of the

dynamics of an electron claimed a large share of his attention. His work on this subject was perhaps mainly critical, rather than novel; but he has done much to reduce the various investigations into systematic relation; his broad outlook has helped to clear a subject of bewildering confusion. To the new developments of thermodynamics and Planck's theory of *quanta*, which appear destined to effect the greatest revolution that physical ideas have yet undergone, he devoted a searching examination. His conclusion, apparently reached with extreme reluctance, was that there can be no escape from at least some of the consequences of these new ideas. Newtonian mechanics is only applicable to matter in bulk, and the ultimate minute constituents demand some other basis of treatment. One result of Planck's *quantum* hypothesis is that it ceases to be possible to represent ultimate dynamics by differential equations. This is a staggering blow at what seemed to be the last article of faith of the mathematical physicist, who, bravely abandoning mechanical models, prepared to throw over the æther and even the electron if need be, yet appeared to have arrived at some ultimate facts of nature in the differential equations which remained.

In no subject has the influence of Poincaré been more widely felt than in his philosophy of science and mathematics. Much of his more technical work is hardly yet appreciated, and it will be many years before the new methods he introduced will reap their full harvest; but his philosophical books, *La Science et l'Hypothèse*, *La Valeur de la Science*, *Science et Méthode*, written in his delightfully clear style, have met immediately with a multitude of readers. They have come to a world which was eager for them. Many scientists are repelled from the ordinary philosophic works, feeling that a hopeless difference of standpoint divides them from the author from the outset. To such the writings of Poincaré come as a complete revelation. His way of thought seems to fill exactly the need of which they are conscious. There must be many of the younger generation of physicists and mathematicians whose philosophical ideas are based almost wholly on his teaching. The view which is particularly associated with the name of Poincaré is his attitude towards space and time and geometry; to him space is neither Euclidean nor non-Euclidean; the postulates of geometry are not to be derived from experiment. No system of geometry is forced on us; we may adopt whichever we will. But a certain geometry may be more convenient than any other, because it enables the facts of nature to be expressed with greater simplicity. Euclidean geometry is convenient because, when it is adopted, we find that light travels in straight lines, and that ordinary bodies are more or less rigid. If, as the principle of relativity tells us, it is found that bodies are not rigid, but systematically change their shape when they are differently oriented, we need not change our geometry though it may be more convenient to do so. "Geometry is a convention, a sort of cloak badly fitted between our love of simplicity and our desire not to depart too far from what our

instruments teach us." Poincaré applied this principle to other physical ideas. "What shall be our position, faced with these new conceptions? Are we going to be forced to modify our former conclusions? Not at all: we adopted a convention because it seemed convenient, and we said that nothing could compel us to abandon it. To-day certain physicists want to adopt a new convention. They are not forced to do so; they consider the new convention more useful, that is all; and those who are not of the same opinion can rightly retain the old if they do not care to disturb their old habits of thought. Between ourselves, I think they will do so for a long time to come."

We have had to examine his work under the different divisions adopted by custom; but it is interesting to trace the unity throughout it all. To quote M. Bosler: "The Fuchsian functions connect themselves with non-Euclidean geometry, which leads to the relativity of space, and that leads straight to the idealism of Berkeley." Poincaré believed that science can only advance "by unlooked-for drawing together of its diverse branches." Perhaps no other man in modern days has broken down so completely the barrier between pure and applied mathematics; he has shown by his example that the physicist may be helped by even the most advanced and specialised methods of pure mathematics. But he was a believer in mathematics for its own sake, apart from its utility and application. "Mathematical science is bound to reflect on itself, and that is well, for to reflect on itself is to reflect on the human mind which created it."

His death took place on 1912 July 17, at a time when in England an unprecedented concourse of scientific men had met together to celebrate the 250th anniversary of the foundation of the Royal Society. The news, which was quite unexpected, cast a gloom over the final days of the meetings. A few months earlier, Poincaré had come over to England to deliver a course of four lectures on mathematical philosophy in the University of London. In August his loss was especially felt at the International Congress of Mathematicians at Cambridge, over which his great fellow-worker Sir George Darwin presided. It is a strange stroke of fate by which in the same year France has lost Poincaré and England Darwin; in many respects their methods of research were in striking contrast, but their names are ever closely linked together by their contributions to astronomy, and it is pleasant to reflect on the mutual appreciation and cordial relations between these two foremost investigators of celestial mechanics.

Poincaré leaves a widow and four children.

He was elected an Associate of the Society 1894 November 9.

A. S. E.

PROCEEDINGS OF OBSERVATORIES.

The following reports of the proceedings of Observatories during the past year have been received from the Directors of the several Observatories, who are alone responsible for the same.

Royal Observatory, Greenwich.
(*Director, Dr. F. W. Dyson, Astronomer Royal.*)

Transit-Circle.—During the year 11,186 observations have been obtained. The Sun was observed 159 times, and the Moon 96 times. Reflexion observations of stars were obtained on 74 nights.

This was the seventh year of work on the present working catalogue, which contains the fundamental stars observable in this latitude, and all stars down to 9^m.0 with a few fainter ones between the limits of Declination 24° to 32° N. (the Oxford Astrographic zone). The number of observations has been maintained at the rate required to complete the catalogue in 10 years, but the portion between R.A. 6^h and 9^h is still considerably behind the rest of the catalogue.

Altazimuth.—During the year 1631 meridian transits have been observed. The Moon has been observed 75 times on the meridian, and 24 times in other azimuths (during the first and last quarters). The number of reflexion observations of stars is 107.

A new eye-end of the Altazimuth with a self-registering travelling-wire micrometer is in course of construction by Messrs. Troughton & Simms.

The Altazimuth Ten-Year Catalogue of Stars (1900.0) from observations made during 1899–1908 has been sent to press. It contains about 2000 stars, consisting of Newcomb Fundamental stars, Zodiacal stars, comparison stars for the opposition of Eros 1900–01, and stars selected for reflexion observations.

Cookson Floating Zenith-Telescope.—During the year 167 plates, each exposed on a group of 4 or 5 Talcott star pairs, have been taken, making with the 32 plates taken in the previous year a total of 199. Of these 8 have so far been rejected, and 133 have been measured in one position; the reduction of these measures is nearly complete. A beginning has been made with the work of duplicate measurement.

Occultations.—17 disappearances of stars occulted by the Moon were observed by one or more observers.

28-inch Refractor.—525 double stars have been measured, each star generally on 2 nights. These consist of—

108	pairs under	0 ^u .5 separation.
136	„ between	0 ^u .5 and 1 ^u .0 separation.
133	„ „	1 0 and 2 '0 „
138	„ over	2 ^u .0 separation.

κ Pegasi has been observed on 5 nights, δ Equulei on 3 nights, and γ Ophiuchi on 12 nights.

Measures of the diameters of the ball and rings of Saturn were made on 7 nights, and of the diameters of Mars on 6 nights.

The partial solar eclipse of 1912 April was observed by Mr. Lewis with the Corbett equatorial, and by Mr. Bowyer with the 28-inch. Times of first and last contacts were noted.

From August 26 to September 21 the instrument was out of use whilst a complete overhaul of the dome was being made. From November 22 to December 17 the micrometer was under repair.

Astrographic Equatorial.—During the year 251 plates have been taken with this instrument, 5 being photographs of Comet Gale (1912a), 51 of Nova Geminorum (2), 5 of selected fields of declination 15° N. or 30° N., to furnish standard magnitudes for the same fields in the Franklin-Adams series of photographs. 145 plates were exposed to fields of the Greenwich zone when at the same altitude as the Pole, and to the Pole itself, as described in last year's Report, for determining the photographic magnitudes of the stars of the Astrographic Catalogue; 87 of these were retained as suitable for measurement. Besides these, 33 plates were exposed experimentally to miscellaneous fields near the Pole, a coarse grating being placed in front of the object-glass of the telescope, with a view to the determination of absolute magnitudes. One of these gratings, made of strips of zinc 7.5 mm. wide, separated by intervals of the same width, gives a series of diffracted images on each side of the central image, differing from it by 0^m.98, 3^m.36, 4^m.48. The first two of these are not sensibly elongated, and are in all respects similar in appearance to ordinary stellar images. The photographs of Nova Geminorum (2) above mentioned were taken with this screen.

The magnitudes of Nova Geminorum (2) between March 15 and April 30 were determined from measures of diameters of the principal and diffracted images on the plates, and the results as far as April 16 have been published (*M.N.*, 1912 April).

The work of determining photographic magnitudes of stars for the Catalogue mentioned below has been continued. In the course of this work it has been found necessary to retake several of the fields already taken and reported last year, and of the 420 fields which formed the original programme for this work there are now on the working lists 50 yet to be taken, and 67 to be measured.

The preparation of the Catalogue of Right Ascension and

Declination of stars of the Greenwich Astrographic Zone has been continued. The precessions and secular variations of stars which are not in the Greenwich Second Nine Year Catalogue for 1900 (about 6250) have been computed, and entered in the copy for press, which is now essentially complete except for the photographic magnitudes. These magnitudes are determined finally for the stars from the Pole to declination 83° , and this section of the Catalogue is in the hands of the printers. The differences between the star places of this catalogue and the corresponding places in the Greenwich Second Nine Year Catalogue (1900) have been analysed with relation to the magnitude of the stars, and the "magnitude equation" of the Nine Year Catalogue for this part of the sky determined. This discussion will form part of the Introduction of the Catalogue.

Thompson Equatorial.—This instrument has been employed chiefly in the determination of stellar parallaxes with the 26-inch refractor, and in photographic photometry with the 26-inch refractor, the 30-inch reflector, and with a 6-inch triplet.

For determining parallaxes 89 plates have been exposed on 32 selected stars; 57 of these were re-exposures in completion of a half-cycle. 30 plates have been exposed on Kapteyn areas (mostly of the Pole)—22 of these being re-exposures in completion of a half-cycle.

For the purpose of standardising the counts of stars on the Franklin-Adams chart plates, 50 plates have been exposed on the Pole, and selected areas with the 30-inch reflector, and 23 with the 26-inch refractor; and 32 plates have been exposed on selected areas, using a wire grating in front of the 30-inch reflector.

For photometric comparison in pursuance of a programme for determining the photographic magnitudes of stars brighter than the 9th magnitude to supplement the similar work for fainter stars with the Astrographic telescope, 83 plates were exposed with the 6-inch triplet lens. Together with the photographs taken last year, this completes the photography of all but 3 of the 84 fields into which the Greenwich zone was divided. These 3 have been taken since 1912 December 31. During the year 64 plates have been measured, and photographic magnitudes deduced; 16 plates still remain to be measured.

With the same lens 20 photographs of the spectrum of Nova Geminorum (2) were taken by applying a 30° prism in front of the lens. A drawing made from these has been published in the *Monthly Notices*.

Including a number of photographs for adjustments, etc., 405 photographs have been taken with one or other of the instruments, viz. :—

with the 26-inch refractor	176	photographs
30-inch reflector	111	"
6-inch lens	110	"
and to test a 4-inch object-glass	8	"

In the beginning of the year, on developing some of the completed parallax plates, it was found that there had been a change in the character of the star images with the 26-inch refractor in the interval. The cause was traced to a change in the adjustment of the crown lens with respect to the flint, and on examination it was not found possible to make a satisfactory and permanent adjustment with the existing construction of the cell of the crown lens, and a new cell was decided on. The crown lens was dismounted on May 3, and the cell sent to Sir H. Grubb as a pattern (with modifications). The new cell was received in July, and the adjustments made by the end of August.

Some trouble has been experienced in the course of the photometric work with the reflector, owing to an uncertainty in the focus of the 30-inch. This is partly due to curvature in the glass of the photographic plate, which is sometimes sufficient in such an instrument as the 30-inch, working at an aperture of $1/4.5$ focus, to cause a serious want of focus at the centre of the field. This was rectified by pressing the photographic plate on to its three bearings with a slightly convex metal plate at its back. This has the effect of making every plate slightly but *constantly* convex, but not sufficient to affect the field of the reflector.

Franklin-Adams Chart Counts.—The number of Franklin-Adams chart plates which have been counted during 1912 is 118, 2 of these being recounts. The stars in 25 regions on each plate are counted and classified according to an arbitrary scale of magnitudes. About 1500 stars are counted on each plate, so as to get an estimate of the average density. Out of the whole number of 206 plates, there now remain only 7 to be counted; 4 of these 7 plates are to be retaken at the Union Observatory, Johannesburg.

The reduction of the counts to the Harvard magnitude scale published by Professor E. C. Pickering has proceeded slowly, owing to the difficulty of getting reflector plates with two equally good exposures (on pole and chart field) of half an hour each. Many plates have been only partly completed, and others with full exposures have had to be rejected on account of bad focus. So far, 36 reflector plates have been used, and a few remain to be measured. A new method of standardising the counts is now being tried, by which the central areas of the chart plates will be compared with the Harvard polar sequence of stars by duplicate exposures of 5 minutes on pole and field, with the 26-inch refractor. This will give the magnitudes of the stars in the central region down to 13^m , and the magnitude scale will be extended to about 16^m by a single exposure on the region, of about 40 minutes' duration, with the 30-inch reflector and a parallel wire grating. The wire is of copper, painted black, of diameter .70 mm., and with a grating space of 5 mm. The difference of magnitude between the principal and first diffracted images is $4^m.01$. As the tension of each of the 150 wires is over 10 lbs., the frame had to be strong, and at the same time it was necessary that it should be light, so that it could be

put on and off easily. At the suggestion of Messrs. Troughton & Simms, it was made of vanadium. It was accurately divided by Messrs. Troughton & Simms, and the stringing was done in the Observatory workshop.

Photoheliograph.—Photographs of the Sun have been taken on 243 days during the year 1912, chiefly with the Thomson photoheliograph up to June 26, and exclusively with the Dallmeyer instrument since. Of these photographs 511 have been selected for preservation, including 28 with double images of the Sun for determination of the zero of position of the wires.

The photographs taken at Greenwich have been supplemented by photographs taken at the Royal Observatory, Cape of Good Hope, under the direction of H.M. Astronomer, Mr. S. S. Hough; the last supply of these received by the end of the year extends to the end of October. In the 12 months ending 1912 October 31 photographs were taken at the Cape Observatory on 304 days, of which photographs 599, including 17 with double images of the Sun for determination of the zero of position of the wires, have been received at Greenwich, the two series together supplying photographs for 334 days out of the 366. Of this number 239 Greenwich and 95 Cape photographs have been selected for measurement. To complete the record 25 photographs from Dehra Dûn and 2 from the Kodaikânal Observatory have been already received, and 4 more are expected to come to hand, leaving only one day, 1912 July 20, unrepresented.

The photographs taken at Greenwich have been measured up to 1912 December 16, and the photographs from the other three observatories as far as they have been received.

The complete photoheliographic results for 1910 have been printed and distributed, and the results for 1911 have been completely printed; the measurements and reductions of the photographs have been completed up to 1912 October 31, and the copy for press of the Daily Results up to the same date is ready for the printer.

On the occasion of the partial solar eclipse of 1912 April 17, 15 photographs were taken with the Thompson photoheliograph; these have been measured, and the deduced results have been communicated to the Society.

The solar activity in 1912 showed a great falling off, even from the low level observed in 1911, but the appearance of two groups of spots in high northern latitudes during the month of December probably indicates the commencement of a new cycle, so that the past year, in that case, will have been the actual year of minimum.

The discussion of the error of the assumed position of the Sun's axis is approaching completion, and the final results will be communicated shortly to the Society.

Solar Eclipse.—An expedition was sent to Brazil to observe the total solar eclipse of October 10. The party consisted of Mr. Eddington and Mr. Davidson, accompanied by Mr. J. J. Atkinson

as volunteer assistant. The instruments were set up at Passa Quatro, a village in the State of Minas Geraes. Unfortunately, heavy rain prevailed throughout the eclipse, and no results were obtained.

Wireless Time-Signals.—Apparatus for receiving the wireless time-signals from the Eiffel Tower was set up on 1912 July 5. From July 6 these signals have been regularly observed, and compared with the Greenwich time-determinations. The results of the comparison are communicated daily to the Director of the Paris Observatory. The wireless signals from Norddeich have also been regularly received and compared.

Apart from the accidental errors of the time-determinations concerned, there is a constant difference, the time-signals being observed late as compared with the Greenwich clock. These differences are—

Observer.	Eiffel Tower.	Norddeich.
Mr. Lewis	0 ^s .25	0 ^s .23
Mr. Bowyer	0 ^s .32	0 ^s .30

This effect (except in so far as it includes personality in receiving signals) may be attributed to the personality of the Greenwich “standard observer” with the transit-circle. It could be made to disappear by a different choice of standard observer.

After correcting for the constant differences, the mean discordances between the Greenwich determinations and the signals are—

Observer.	Eiffel Tower.	Norddeich.
Mr. Lewis	± 0 ^s .13	± 0 ^s .23
Mr. Bowyer	± 0 ^s .14	± 0 ^s .24

Printing.—The Greenwich observations for 1910 were distributed in July. The printing of the 1911 volume is nearly complete.

The third volume of the Astrographic Catalogue is in the press. The small catalogue of Rectangular Co-ordinates of 2212 stars near the North Pole (referred to in the last report) has been printed and distributed, and the printing of the Catalogue of Right Ascensions and Declinations, which forms part of the same volume, has been started.

Royal Observatory, Cape of Good Hope.
(Director, Mr. S. S. Hough, H.M. Astronomer.)

Transit-Circles.—A new observing programme with the new transit-circle was commenced at the beginning of the year. The working list of stars contains all the Boss fundamental stars not included in the previous working list, together with the Backlund-Hough stars visible in this latitude.

The old transit-circle has been used for occasional time determinations.

With these instruments the following observations have been obtained during the year:—

Observations of Right Ascensions:—

	Reversible T. C.	8-in. T.C.
Number of meridian transits .	8150	73
Determinations of collimation by		
collimators	128	8
„ by reflexion and		
reversal	28	
Determinations of level . .	794	16
„ azimuth . .	164	4
Observations of Meridian Marks . .	1442	

Observations of Zenith Distances:—

Determinations of Z.D. . .	7512
„ runs . .	346
„ nadir . .	756
„ flexure . .	52

The observations with the reversible transit-circle include observations of the Sun on 130 days, of Mercury on 51 days, and of Venus on 63 days.

In connection with the reduction of the circumpolar observations made during the previous year, some experiments have been made by causing the travelling wire to transit at varying speeds over the meridian marks, regarded as artificial stars, with a view to the determination of personality dependent on rate of motion. These experiments show that, with the method of observing actually employed for the circumpolar programme, such personality, in that it operates in the same direction for all observers who have been tested, is of considerable significance. They further appear to indicate that while, for the most part, observers using the older methods of observing are late in recording the transits of equatorial stars, they all appear to agree in anticipating the transits of slow moving circumpolars to an average extent of about 0^s.3.

In consideration of the high degree of stability of the meridian marks shown by the R.A. observations of circumpolar stars during the year 1911, these observations have been carefully analysed for a determination of the constant of aberration. The derived value for this constant is $20''.45 \pm 0''.02$.

The ledgers of observations made in previous years have been completed to the end of 1908 and of the Right Ascensions of Time and Azimuth stars to the end of 1911. A discussion of the observations for the purpose of determining the periodic errors in R.A. dependent on the R.A. has been completed and the results communicated to the Society.

Helimeter.—The observations of major planets at the time of opposition have been continued, and the following secured :—

Opposition of Neptune	.	39 obs. of distance on 7 nights.
„ Jupiter .	.	39 „ „ 7 „
„ Uranus .	.	48 „ „ 8 „
„ Saturn .	.	36 „ „ 5 „

The results of observations made during the years 1905 to 1910 have been published in *Cape Annals*, vol. viii. part 3.

Victoria Telescope and Astrophysical Laboratory.—The instrument has been continuously employed in conjunction with the four-prism spectrograph train for the photography of stellar spectra. Observations were obtained on 188 nights, and in all 467 plates of stellar spectra were secured, in addition to 57 daylight plates and 34 focus plates.

During the year 786 stellar plates have been measured in the Hartmann comparator. Of these plates 653 are in connection with the special programme for the spectroscopic determination of the solar parallax and the constant of aberration.

A provisional determination of these quantities derived from about 800 plates gave as the value of the solar parallax $8''.802 \pm 0''.004$, or of the aberration constant $20''.47 \pm 0''.01$. The observations are remarkably consistent and show no evidence of the results being affected by defects of instrument or method.

173 photographs of spectra of metals, graphites, etc., have been obtained in the laboratory, and a discussion has been made of the spectrum derived by sparking between terminals obtained from the cores of lead pencils. These spectra, which give a large number of sharply defined lines throughout the region usually employed in the stellar work, have been found convenient as comparison spectra, and have recently been employed in laboratory investigations of metallic spectra in preference to the comparison spectra of iron or titanium.

Astrographic Telescope.—With this telescope the following photographs have been obtained during the year :—

Description of Plate.	No. of Plates.	No. of Exposures.	Duration of Exposure.
Magnitude plates . . .	2	8	20 ^m , 6 ^m , 20 ^m , 6 ^m
Plates taken for Greenwich .	12	24	20 ^m , 20 ^m
Nubecula Major . . .	14	14	5 hours
Nova Geminorum . . .	3	9	various
Hector . . .	6	10	„
Achilles region . . .	6	10	„
Comet Brooks . . .	11	12	„
Comet Quénnisset . . .	8	9	„
Comet Gale . . .	18	35	„
Comet b 1912 . . .	19	20	„

The regions photographed for Greenwich were taken at the request of the Astronomer Royal as supplementary to the observa-

tions secured at Helwân of Jupiter's eighth satellite. The plates of the Nubecula Major were taken at the request of Mr. Hinks and have been forwarded to him for discussion; those of the planets Hector and Achilles at the request of Professor Strömgren.

"Carte du Ciel" Reductions.—During the year the application of the plate-constant corrections has been completed and a copy for press of the measures, subject to final control, prepared for the 611 plates outstanding from the previous year. The identification of the stars by comparison with the C.P.D. has been completed for 500 plates.

The control computations necessary to facilitate the comparisons of overlapping areas, which are being used as a final control of the results, are in various stages of advance, 157 being nearly completed, but only 18 plates having been finally passed for press during the year. The whole of the MS. for zone -41° has been forwarded to the printer, and proof sheets have been passed for the first 61 plates.

Photoheliograph.—Daily photographs of the Sun to supplement the Greenwich series have been secured on 296 days. In all, 615 negatives were taken, including 8 taken during the partial eclipse of the Sun on October 10. Of these negatives 592 have been selected for transmission to Greenwich for inclusion with the Greenwich series.

Occultations.—Twenty-three separate phenomena of occultations of stars by the Moon have been observed during the year, viz.:—

Disappearances at dark limb	.	.	.	17
Reappearances	„	„	.	6

Of these four were observed by two observers.

Miscellaneous.—The time-signal service, meteorological observations, and seismograph records have been maintained as in previous years.

Royal Observatory, Edinburgh.

(*Director, Professor R. A. Sampson, Astronomer Royal
for Scotland.*)

Transit-Circle and Clocks.—Observations with the Transit-Circle have been confined to those necessary for time service in the Observatory and the town. Mean time service to the town has been controlled hitherto by the clock Molyneux. As this stands in a somewhat exposed position, and its case must be opened daily to add or remove weights upon the pendulum, its performance has been occasionally uncertain. To improve the service a clock by Riefler of Munich has been acquired and was set up in July in the clock cellar. It gave at first some trouble owing to a defect in the sealing of its air-tight case, but since this has been cured it shows promise of very excellent performance. As the temperature of the cellar fluctuates smoothly from winter to

summer over about 20° F., the going of the clock is affected by the consequent variation of pressure within the case. A thermostat, consisting of a contact thermometer actuating a relay which turns on or off an electric radiator, is in course of installation. When Rietler's clock is finally regulated, it is proposed to keep both Rietler and Molyneux in constant adjustment to mean time, and by means of a switch-board to throw over from one to the other at will the control of the town service and that of the controlled clock in the lobby of the Observatory which actuates the signals for the seismograph.

Solar Spectroscope.—Observing weather was exceptionally bad throughout 1912, except for the months of April and May. During these months a number of photographs were taken to test adjustments and to complete changes which were in progress last year. Exposures were made chiefly on the infra-red portion of the spectrum, with plates dyed with alizarine blue, to examine the oxygen triplet $\lambda 7772.5$ for a Doppler displacement from opposite limbs of the Sun. In spite of the weather satisfactory results showing the solar origin of these lines were obtained in September, and a paper giving an account of these was published in *Monthly Notices* for November last. The long exposures necessary, amounting in the case of the best plate to one hour, put the stability of the instrument to a severe test which it satisfied successfully.

Fifteen-inch Equatorial.—Double-star observations have been continued as occasion served upon the same plan as heretofore. Two prismatic cameras are at present attached to the instrument, one furnished with prism of Iceland spar, and lens of quartz corrected with Iceland spar. With these several exposures were made upon Nova Geminorum (2). With the Iceland spar camera several exposures have been made upon gaseous nebulae, but it seems doubtful if the instrument is powerful enough for this work. Exposures were also made upon Comet Gale, but with the faintness of the Comet and the abnormally bad weather no measurable results were obtained.

Reflector.—The twenty-four-inch reflector has not been employed upon any regular work, owing to the defects mentioned in the last report. With a view to making plans for a better instrument, a study has been made of the possibility of correcting the faults of field of a reflector and a plan arrived at, which seems feasible in practice, of correcting the field of a Cassegrain by means of interposed lenses. A memoir describing this investigation has been communicated to the Royal Society.

Seismograph.—Photographic observations have been made regularly with the Milne seismograph, the records read, and the results for 1912 communicated to Dr. Milne. The usual oil lamp illumination has been replaced by an Osram three-candle-power lamp fed by three accumulators and regulated to a suitable brightness with an adjustable resistance. The results are very satisfactory.

Meteorology.—Meteorological observations have been carried on regularly, as also those of the Kelvin water-dropping electrograph. A comparison of the records of the latter, with others taken concurrently by Dr. Carse at the University, show agreements and identities of striking character, in view of the separation of the two instruments and the very different circumstances of exposure. These are at present under detailed examination.

Astrographic Catalogue.—Measurement of astrographic plates taken at Perth, Western Australia, has been continued. In all ninety-one plates have been measured during the year, including nine of Zone -40° (these being remeasurements for defective plates) and eighty-two of Zone -38° . This exhausted the plates received, as Perth Observatory, owing to uncertainty as to its future, was unable to keep us supplied with any margin. Copy for press has been made of all the measures.

Cambridge Observatory. (Director, Sir R. S. Ball.)

1. *Meridian Circle.*—During the year very little progress has been made with the completion of the observations for Gill's Zodiacal Catalogue. There are now large tracts of the working list where the observations are complete, and the small number of observing nights during the year were not well arranged with respect to the parts where observation is still required. 178 stars were observed on nine nights. The reductions to apparent place are calculated to 1908 October 7 in Right Ascension, and to 1910 September 20 in N.P.D. The reductions to mean place are calculated to 1908 October 7.

The printing of the Ledger of Zone Catalogue observations is complete to R.A. $20^{\text{h}} 45^{\text{m}}$.

So far as possible clock stars are observed daily, and the Graham clock adjusted to Greenwich time.

Mr. Hartley has been in sole charge of the observations and reductions in this department.

2. *Sheepshanks Telescope.*—Some progress has been made with the measurement and reduction of the stellar parallax series mentioned in the report of last year.

Observation has been principally in connection with the work on classification of nebulae now in progress. Much valuable material has been contributed by Mrs. Isaac Roberts, from the collections of the late Dr. Roberts; by the Royal Observatory, Cape of Good Hope; Harvard College Observatory; the Lick Observatory; Helwan Observatory; the Union Observatory, Johannesburg; and by Mr. Henry Ellis. In particular, a fine series of nine plates of the Great Magellanic Cloud, taken with the Cape Astrographic telescope with five hours' exposure, has been made especially for this work under the direction of Mr. Hough. A classification of

the nebulae and clusters in the cloud has been made from these plates, and will be communicated to the Society at an early date. The general enterprise of determining the galactic distribution of spiral nebulae is also making excellent progress, and it is hoped that it will shortly receive a notable addition as the result of the examination of the Franklin-Adams plates by Mr. Hardcastle, which is now almost complete.

The last sheets of the Catalogue of the photographic positions of stars determined with the planet Eros in 1900-01 have been passed for press, and the work will appear shortly as tome vi. of the *Bulletin du Comité Permanent*.

3. The usual courses of instruction in practical astronomy, and in field astronomy for surveyors and geographers, have been given by Mr. Hinks during the year.

*The Newall Telescope, and Astrophysical Department,
Cambridge Observatory. (Professor H. F. Newall.)*

The Newall telescope has been used in two spectroscopic investigations during the past year. In the one, photographs of the spectra of α Boötis and α Lyrae have been obtained under high dispersion, with the twofold purpose of searching for signs of periodic change in the spectrum of the first-named star, and of testing the performance of a grating ruled by Dr. Anderson of Baltimore—a grating which gives an unusually bright spectrum of the second order.

The second main task to which the 25-inch telescope has been devoted has been the study of the spectrum of Nova Geminorum No. 2. Enebo's discovery of this star came near the end of a long spell of bad observing weather. Photographs were secured with the two-prism spectrograph by Mr. Stratton and Mr. Manning on 9 nights in the latter half of March and on 25 nights in April. The last plate secured before the nova was lost in the evening twilight was taken on May 13. The nova was re-observed visually on August 13, and photographic observations were resumed on December 6 with a new spectrograph with a single quartz prism. The spectrograms are now being measured and reduced. Preliminary results have been reported to the Society.

Mr. Stratton has also been engaged with Professor Newall in an examination of the series of photographs of the spectrum of Nova Persei secured in 1901 and not yet fully discussed.

The new spectrograph for the Huggins refractor is nearing completion. Meanwhile the refractor has been used for visual observations of the spectrum of Nova Geminorum. With the reflector Mr. Brunt has examined photographically the ultra-violet spectrum of the nova and some gaseous nebulae.

Interesting results were obtained by Professor Newall in photographing with high dispersion the spectrum of the limb of

the Sun during the partial eclipse of the Sun 1912 April 16-17. They were communicated to the Society in May (*M.N.*, lxxii. 536).

The work on the solar rotation by spectrographic methods has been continued, and Mr. Hubrecht has completed a paper setting forth the results of his researches—a first contribution to the co-operative scheme organised by the International Union for Solar Research at their meeting at Mount Wilson in 1910. Mr. Hubrecht's results relating to two regions of the spectrum, 4200-4300 and 4300-4400, were communicated to the Society in November (*M.N.*, lxxiii. 5-27).

Mr. Capstick has continued his photometric researches on the relative intensity of lines in widely separated regions of the spectrum of the electric arc under varied conditions. A Hartmann microphotometer made by Messrs. Toepfer of Potsdam has been obtained for this and other photometric work.

Mr. R. Rossi of Trinity College has joined the Observatory as an advanced student. He has measured and studied spectrograms of α Boötis obtained in 1902, and is working in the laboratory on the widening of the hydrogen lines.

Lectures have been delivered by Professor Newall on Solar Physics, and by Mr. Stratton on Stellar Physics.

New buildings were begun in September in preparation for the transfer of the Solar Physics Observatory to Cambridge in April 1913, and are well advanced towards completion.

Dunsink Observatory.

(*Director, Professor H. C. Plummer, Royal Astronomer of Ireland.*)

Professor Whittaker resigned the position of Royal Astronomer of Ireland on March 31 in consequence of his appointment to the chair of mathematics at Edinburgh University. Mr. H. C. Plummer was appointed to succeed him on May 4, and assumed the duties of director at the beginning of June. Mr. C. Martin continues to act as Assistant.

The time-service to Dublin has been continued as in previous years, and the Pistor and Martins meridian circle has been used only for the determination of time.

The past year was very unfavourable for observations, particularly during the summer months. With the Roberts reflector 271 plates have been taken for the study of variable stars. The programme has been slightly modified, the observation of certain irregular variables having been temporarily discontinued in view of the difficulty of following their variations continuously owing to climatic conditions. These stars have been replaced by short-period variables, and an investigation of SU Draconis has been completed for communication to the Society.

The Director, in addition to the discharge of certain academic

duties, has continued his discussion of the systematic motions of the stars based on the radial motions chiefly determined at the Lick Observatory and at Santiago (Chile).

According to custom, the South Equatorial has been used to show objects of interest to visitors on the first Saturday of each month.

The University Observatory, Durham.
(Observer, Mr. F. C. H. Carpenter.)

During the past year observations made with the almucantar and their reduction have been the principal work of the Observatory.

The telescope was dismantled in November 1911 and sent to Messrs. T. Cooke & Son of York to have some alterations made. It was returned here in February 1912, and erected with careful attention to the adjustments.

Between 700 and 800 stars have been observed with it, and these reduced with a view to ascertain the behaviour of a floating instrument and also the determination of the variation in latitude.

A paper on the results is in preparation, and will shortly be presented to the Society. Regular meteorological observations have been made and reports sent to London. Lectures in astronomy and optics have been delivered at the University by the observer.

Major E. H. Hills, C.M.G., F.R.S., has been appointed Honorary Director of the observatory.

Glasgow Observatory. (Director, Professor L. Becker.)

The new star in Gemini was repeatedly photographed with the large spectrograph and a small prismatic camera. Of the solar eclipse on April 16-17 only the last contact could be observed owing to clouds.

A novel instrument, which will be one of the essential parts of a Photographic Transit Instrument, was delivered by the Cambridge Scientific Instrument Co. about the end of April. A horizontal camera fixed in the meridian is fed by a mirror clamped normal to the meridian. As stars of a certain zone pass the meridian their images very nearly describe circles round a common centre and at the same angular speed. The instrument now installed moves a plate round this same centre at the velocity at which the images move, with the effect that the images will be photographed as points. The device for carrying the plate in a circle is due to Mr. Horace Darwin and is based on the following geometrical consideration: Consider a small arc of a circle of radius r intersected by a chord, and a line of constant length AB ,

where A moves on the circumference of the circle, and B on the chord. A point C , fixed on AB between A and B , then moves very nearly in a circle the radius of which lies between r and infinity, and to each radius between these limits a definite position of C belongs. On investigating the problem theoretically, the Director found that the accuracy thus obtainable was more than sufficient, and the device, in point of simplicity, preferable to the one which he had submitted to the firm.

The instrument has two rails, a horizontal one and a circular one of 2 metres radius, and two carriages AB . The plateholder is supported by both carriages at two corresponding points C , whose positions are obtained by means of divided scales. Experiments have been carried out with the instrument with most satisfactory results, and they will be continued when the photographic camera has been procured.

The time-service and meteorological observations have been carried on as in former years.

Liverpool Observatory. (Director, Mr. W. E. Plummer.)

The work of the observatory goes on as in previous years, with little alteration. The small staff is mainly engaged in meteorological observations, the testing of chronometers and instruments submitted by makers, and the distribution of accurate time-signals. With regard to the last, it may be mentioned that the Mersey Docks and Harbour Board have sanctioned the installation of a wireless receiving apparatus for observing the time-signals from Paris and Norddeich. The object is not only to secure greater accuracy in cloudy weather, but to interest the Officers of the Mercantile Marine in a scheme by which they may obtain improved chronometer rates at sea. The observations of these time-signals is possible as far as St. Vincent, but the navigating officers have, as a rule, shown themselves indifferent to the advantages to be gained.

The alterations in the seismometer, mentioned in the last report, have been very efficiently carried out by Mr. J. J. Shaw of West Bromwich, and the efficiency and economic working of the machine have both been improved. It is proposed to apply the same method of registration to the record of tidal displacements, which, when carried out, will prevent many of the irregularities that were caused by the frequent approach of the observer to the instrument for clock winding and general attendance.

The Equatorial, which is not provided with any photographic apparatus, is actively employed in the observation of comets and double stars.

Radcliffe Observatory, Oxford.
(Director, Dr. Rambaut, Radcliffe Observer.)

The work at the Radcliffe Observatory during 1912 has been conducted on much the same lines as in recent years.

The 24-inch photographic refractor has been chiefly employed in connection with the plan, described in the report of this Observatory for 1909 (*Monthly Notices*, lxx. No. 4), for determining the proper motion of stars in selected areas down to the 14th magnitude. Throughout the year the weather has been most unfavourable for astronomical photography at Oxford, and, especially in the latter half, has been marked by an unusual amount of cloud. In connection with the proper motion scheme only 38 plates have been obtained, and of these 2 were incomplete, leaving 36 which were considered satisfactory, very little more than half the number (67) obtained in the preceding year. During the year 12 plates have been packed up undeveloped and stored in air-tight boxes.

Other objects photographed with this instrument include: Nova Geminorum No. 2; the new variable 17, 1912 Aurigæ; and the region of the Pole. During the partial eclipse of the Sun of April 16-17, eighteen photographs were also taken with this instrument, using an instantaneous shutter of special construction. These photographs, which are of exquisite sharpness, have been fully measured, and the computations necessary for deducing corrections to the Moon's diameter, and to the differences in R.A. and Decl. of the centres of the two bodies, are well advanced.

The 18-inch refractor, when not in use as guider to the 24-inch photographic equatorial, has been used occasionally for observations of variable stars. The 10-inch Barclay equatorial has been employed for miscellaneous observations, including observations of Nova Geminorum No. 2 on 32 nights, and observations of the contacts and other phenomena during the solar eclipse of April 16-17. It has also been used by Mr. Barrett in his leisure time for observations of RW and ST Draconis, 17, 1912 Aurigæ, and other stars. Of these he has made 385 comparisons spread over 23 nights. The observations of Nova Geminorum No. 2, made with the 10-inch Barclay, as well as a number of observations of the same object made with smaller apertures, and with the naked eye, have all been reduced, and the results communicated to the Society in two papers published in the *Monthly Notices*, lxxii. Nos. 6 and 8. Attention may here be called to Mr. Barrett's discovery of the variability of the star 17, 1912 Aurigæ in the course of an examination of the photographs. The results of his observations are contained in two notes communicated to the *Astronomische Nachrichten*, Nos. 4559 and 4620.

Very satisfactory progress has been made during the year in the measurement and reduction of the parallax plates taken in recent years with the 24-inch refractor. In all 69,137 measures of

21 parallax plates have been made, to which must be added 3479 measures of the solar eclipse plates, making altogether 72,616 measures of photographs taken with this instrument during the year. With one exception, the measures of these parallax plates have all been reduced, the parallaxes determined, and the results carried into the card-catalogue as a preliminary step towards preparing them for press. Of these 21 plates, one had been measured last year but was re-measured during 1912 with a different micrometer from that ordinarily attached to the measuring machine, two were taken on Kapteyn's plan, and the remaining 18 formed 9 pairs of "split triples." As explained in the report of this Observatory for last year, a "split triple" consists of two plates, one of which contains three exposures made at the first selected epoch of maximum parallax factor, and three at the second selected epoch. On the other component of the pair are three exposures made at the second epoch and three at the third. The card-catalogue now contains, in addition to those enumerated in last year's report, 795 separate determinations of the parallaxes of 363 stars in the region of Nova Persei; 146 separate results for 86 stars in the region of the Hyades; and 254 separate results for 254 stars in the region of B.D. $+51^{\circ}1094$, of which four plates remain to be discussed. If we add these figures to those given last year we find that, in all, 2490 separate determinations of the parallaxes of 1188 stars are contained in the card-catalogue. In addition to these there are the parallaxes of 192 stars deduced from a single plate representing the region surrounding B.D. $+41^{\circ}750$, and 183 separate determinations of the parallaxes of 75 stars in the region of B.D. $+25^{\circ}495$, deduced from measures of five of the Oxford plates by Professor Kapteyn at Groningen, which have not been entered in the card-catalogue.

Early in the year vol. i. of the *Radcliffe Observations*, containing the results of the meteorological observations made at this Observatory during the years 1906-1910, was printed and published. Vol. ii. part i., containing the results for the year 1911, was also printed, whilst vol. ii. part ii., covering the year 1912, is now in the printer's hands.

During the year an electric light installation was set up throughout the observatory, which had hitherto been illuminated by gas.

University Observatory, Oxford.
(*Director, Professor H. H. Turner.*)

The first part of volume viii. of the *Astrographic Catalogue* is nearly through the press. It gives the approximate mean corrections to the Cambridge A.G. Catalogue as deduced from the Oxford plates. The corrections contain proper motions for the interval (20 to 40 years) between the dates of Cambridge meridian observations and the dates of exposure of the Oxford plates; but

these are in general small—certainly much smaller than the systematic errors due to magnitude equation in the Cambridge Catalogue, and its variations. The importance of studying these variations was suggested by the first plate exposed as an experiment in re-observing the Cambridge stars by a photographic method (see *Mon. Not.*, lxxii. p. 110), and, in order to investigate it thoroughly, it was determined to complete the revision of the ledgers of differences (Oxford – Cambridge) as soon as possible. This work (the result of which is now being printed as above) has thus absorbed a large part of our energies during the past year. As soon as it was sufficiently complete, Mr. Bellamy undertook a preliminary survey from the “single observations” (*Mon. Not.*, lxxiii. p. 88), and a general investigation was started with cards. This is now finished and nearly ready for press. The suspicion that the magnitude equation varied widely is fully confirmed, the range for stars of magnitude 9.5 amounting to 0^s.15, while between two different observers whose observations are treated in the Catalogue as consistent there is a difference of more than 0^s.30. It seems clear that visual observations of faint stars are liable to systematic errors of an amount which render them of very doubtful value for correcting the much more accurate photographic measures.

The work of re-observing the reference stars for zone +29° by the photographic method has been somewhat delayed, with intention, by the above investigations. But 12 plates, containing in all 368 exposures, have been taken during the year: and 25,000 measures of some 5000 reference stars have been made and partly reduced.

By the help of a kind subsidy from Mr. A. F. Lindemann, and afterwards of a grant from the Vatican Observatory itself, the reductions of the Rome portion of the Astrographic Catalogue (+64° to +55°) are being undertaken here. The measures are made in Rome and the results sent to this Observatory, where arrangements are made for computing and the work is superintended. Zone +64° is practically ready for press, and a large part of zone +63° is done. The initial stages of this work naturally occupied a good deal of time, but it is now going rapidly and smoothly.

It has been shown in two papers (*Mon. Not.*, lxxii. pp. 464 and 700) that it is feasible to determine with sufficient accuracy the errors of the magnitude scales of the Astrographic Catalogue by simply counting the number of entries under each heading. The systematic errors are so large that it seems doubtful whether the refined investigations suggested at the last meeting of the Committee are suitable for the correction of such estimations of magnitude as are made in the ordinary course of this work: though, of course, the investigations will have an independent value of their own.

A good deal of harmonic analysis, on the lines of Professor Schuster's periodogram method, has been done incidentally, especially in the examination of the periodicities of earthquakes (see B. A. report) and of the variations of level and azimuth of the

Greenwich and Cape Transit Circles. This work is nearing completion.

The preparation of Baxendell's observations of variables has also taken some time. One star (R Arietis) has been completed (*Mon. Not.*, lxxiii. p. 124), and several others are practically ready. Out of this work came incidentally the discovery that S Persei had a periodogram like that of the Sun (*Mon. Not.*, lxxiii. p. 116), which is an important piece of evidence for the classification of these long-period variables with the Sun, as suggested in former papers. (See *Mon. Not.*, lxvii. 332.)

The Observatory has lost the valuable services of Mr. H. C. Plummer, through his appointment to the post of Royal Astronomer of Ireland. Before leaving the Observatory in June he presented a second paper on the hypothetical parallaxes of the A and B stars, on the assumption that they are moving parallel to the Galaxy, and a third paper has recently been communicated from Dublin. Not only are the results of his work striking in themselves, but they proved valuable in working out the consequences of a suggestion for explaining the appearance of "two star-streams," viz. : that the streams are merely the outgoing and incoming members of the same star community, moving with oscillatory motions under the integrated gravitational attraction of the whole community. The resultant attraction is approximately to a centre in the direction 94° , $+12^{\circ}$, at about ninety light years' distance.

The vacancy caused by Mr. Plummer's departure has not yet been filled. Miss E. F. Bellamy has been given a definite position on the staff.

The Coats Observatory, Paisley.
(Convener, Mr. John Woodrow.)

On clear nights clock-star observations have been duly made and the standard mean time clock regulated.

Time-signals are flashed hourly by this clock to the works of Messrs. Coats & Clark, thread manufacturers, and to the galvanometer of the George A. Clark Town Hall for the purpose of checking the clock.

The "earth tremors" recorded by the Milne seismograph are half-yearly communicated to Professor John Milne, F.R.S., Shide, for publication in the British Association Annual Report. On Dr. Milne's recommendation the most recent type of seismograph has lately been purchased. The Richard anemometer, which had done duty for over twenty years, has been replaced by the most modern form of anemograph, Dines-Baxendell pattern.

The transit instrument, which has been in constant use since the founding of the Observatory (1883), has been completely overhauled by the makers, Messrs. Troughton & Simms.

The solar eclipse of 17th April last was watched through the equatorial, and several photographs were secured.

Temple Observatory, Rugby.
(Director, Mr. G. M. Seabroke.)

The usual educational work has been carried on at this observatory, and the attendance of boys has been considerable and it is hoped that some may carry away a taste for astronomy. Some double stars have been measured by Mr. Hulett, who is taking up the work.

Royal College of Science, South Kensington.
(Assistant Professor, A. Fowler, F.R.S.)

As in former years, the instruments were chiefly utilised for the instruction of students, but observations of the spectra of sun-spots and metallic prominences were continued as opportunities occurred. Visual and photographic observations of Nova Geminorum were made by Mr. Curtis (*M.N.*, vol. lxxii. p. 511). The large partial eclipse of the Sun, April 17, 1912, was observed under almost ideal conditions, and valuable information was obtained as to the time during which the spectrum of the reversing layer could be effectively observed at the cusps (*M.N.*, vol. lxxii. p. 538). Preparations are being made to extend these observations during the total eclipse of August 20, 1914.

The most important outcome of the laboratory work was the production of the previously hypothetical Principal and Sharp series of hydrogen lines, together with a hitherto unsuspected ultra-violet series, by passing strong discharges through a mixture of hydrogen and helium (*M.N.*, vol. lxxiii. p. 62). Experiments relating to the outstanding features of the spectra of comets were continued, but no important progress was made. A paper on "The Spectrum of Comet Morehouse" was published (*Astrophys. Jour.*, vol. xxxv. p. 85).

Solar Physics Observatory, South Kensington.
(Director, Sir Norman Lockyer, K.C.B.)

Observations of Sun-spot Spectra.—The Sun was visible on 227 week-days during 1912, and observations of sun-spot spectra were made on five days, five spots being examined in the F-b region. The chief widened lines are still those due to vanadium, titanium, magnesium associated with hydrogen, and to scandium.

Spectroheliograph.—Attempts to secure photographs of the Sun in " K_{2-3} " light with this instrument were made on 107 days. 115 negatives showing distribution of calcium flocculi were taken, and of these 110 have been selected for measurement. In addition to these, nine "limb" negatives were obtained showing prominences.

In accordance with the arrangement made with the Indian Government, 332 spectroheliograms showing the disc in "K" light have been received from the Kodaikámal Observatory during 1912. These cover the period October 1, 1911, to September 30, 1912.

Areas of Flocculi.—The measurement and reduction of the composite series of daily spectroheliograms from Kodaikámal and South Kensington have been completed to the year 1908; in addition, measures have been made in duplicate to October 4, 1909, and by one observer to March 31, 1912.

Sun Photographs.—Daily photographs (glass negatives) of the Sun's disc, taken with the photoheliograph, have been received from Dehra Dûn and Greenwich.

Positives on paper are also received from Dehra Dûn, and these are mounted on cartridge paper and bound up in yearly volumes. Where necessary to fill gaps, prints are made from Greenwich plates, and latterly also from Kodaikámal and Cape negatives.

Night Work.—Observers attended on 143 nights, and photographs, afterwards indexed, were obtained on thirteen nights. Three spectrograms of Nova Geminorum (No. 2) were secured with the 36-inch reflector.

With the 6-inch Henry prismatic camera twelve photographs of nine stellar spectra were taken.

The 9-inch prismatic camera has been mounted in place of the 2-inch calcite-quartz spectrograph, and has been brought into partial adjustment.

Publications.—During the year a paper on "The Spectrum of Comet Brooks (1911c)" has been published in the *Proceedings of the Royal Society*, and a "Report of the Solar Eclipse Expedition to Vavau" has been published by the Solar Physics Committee. Papers in connection with the spectra of the Orion stars, the spectrum of α Orionis, and the causes which produce the phenomena of new stars, are nearly ready for publication.

Stonyhurst College Observatory.
(Director, Rev. W. Sidgreaves, S.J.)

In 1912 the solar surface was observed on 183 days, and drawings of spots and faculæ were made on 60 days. The surface was found quite free of spots on 140 days, and quite free of both spots and faculæ on 123 days. The mean daily disc area of spots for the year was 0.22 (unit 1/5000), and the percentage of spotless days 76. These figures indicate a very low minimum, the corresponding figures for 1901 having been 0.29 and 39. But there are signs that the minimum is at end, as a small group of spots was observed on December 17 and 18 in latitude 20° N., longitude $226^{\circ}5$.

Such spots as have appeared have been beyond the power of

the grating solar spectrometer, and consequently no work with this instrument has been attempted during the year. A reduction of the sun-spot and terrestrial magnetic phenomena for the last solar cycle has been begun, and two papers on the subject have already been presented to the Society (*Monthly Notices, R.A.S.*, lxxiii. pp. 52, 148).

The spectrum of Nova Geminorum No. 2 was photographed on 7 days with the 15-inch equatorial and the Hilger compound prism, and was visually observed with an eyepiece spectroscope on 5 other days (*M.N., R.A.S.*, lxxii. p. 714).

Photographs of the partial solar eclipse of April 17 were taken with the Abney lens, and the last contact was observed over the chromosphere (*M.N., R.A.S.*, lxxii. p. 542). A thorough spectroscopic examination of the Sun's limb was made on October 10, the date of the total solar eclipse (*M.N., R.A.S.*, lxxiii. p. 51).

Some visual and photographic observations were made of comets Gale and Borrelly.

The Whitelow six-inch portrait-lens-camera has been recently fitted with a six-inch prism of 19° angle, presented by the same donor; and the camera with its prism bears the name:—Whitelow Prismatic Camera. The prism is the work of Mr. Thorp of Whitefield, Manchester. It does full justice to the Dallmeyer lens: the definition seems perfect on all parts of a quarter-plate from D to H η . But the weather, so far, has been against any long enough exposure on small bright line stars.

Wolsingham Observatory (Rev. T. E. Espin).

The examination of Argelander's stars in the selected zones has been continued during the year. The new double stars detected have been communicated to the Society. A few known double stars have been measured during the year. Observations have also been made of Nova Geminorum (2), Nova Lacertæ, and R Cygni.

Mr. D'Esterre's Observatory, Tatsfield.

The instrumental equipment consists of a 15-inch Newtonian reflector of 74.5-inch focus, adapted for both photographic and visual observation. The tube of this instrument is of a square skeleton construction, and carries on one side three portrait-lens cameras, viz. a Voigtländer of $6\frac{1}{2}$ -inch aperture and 30-inch focus, and two Dallmeyer cameras of $3\frac{1}{2}$ -inch $\times$ $12\frac{1}{2}$ -inch and $2\frac{3}{4}$ -inch $\times$ 8-inch focus respectively, and on the opposite side is mounted a 5-inch guiding refractor. There is also a $2\frac{3}{4}$ -inch guiding telescope attached direct to the Voigtländer lens and camera. The guiding in the case of the reflector is effected by means of an adjustable slide plateholder.

The three cameras are regularly employed in photographing selected regions as frequently as possible, with a view to the detection of variable stars and novæ, and in order to obtain records of known variables. The plates are developed and compared by superposition as soon as possible after they are obtained.

When an object of interest is detected, it is followed up with the reflector both visually and photographically.

The following is a list of the plates obtained to 1912 December 31 :—

Instrument.	Date of First Exposure.	No. of Plates.	Hours Exposure.	Area of Plate.	Scale.
15-in. Reflector	1911 July 21	149	133 ^h 45 ^m	4 sq. degrees	1 ^{mm} = 106"
6½-in. Voigtländer	1911 April 29	355	169 ^h 13 ^m	40 "	1 ^{mm} = 262"
3½-in. Dallmeyer	1912 Sept. 12	55	34 ^h 10 ^m	180 "	1 ^{mm} = 650"
2¾-in. Dallmeyer	1911 Aug. 25	290	132 ^h 43 ^m	170 "	1 ^{mm} = 1000"

The objects discovered have been carefully followed up, and are as follows :—

Var. 86, 1911.—Ninety-seven plates cover the region of this object, and it has been observed visually on 16 nights. It is a variable star, period about 365 days, last maximum 1912 October 1, range of photographic magnitude 10^m.2 to 14^m.2, visual range 9^m.5 to <13^m.5, colour near maximum very red. Rise and fall both very gradual. It has a companion distance 14".5, pos. angle 75°, magnitude 15.2. See *A.N.*, 4544.

Var. 87, 1911.—One hundred and twenty-one plates are available for the photographic study of this object, but although the region has been frequently observed visually since 1911 December 14, it has been persistently below the limit of the 15-inch reflector. It rose from certainly <14^m.0 and probably <16^m.0 to an observed maximum of 10^m.5, 1911 November 13, in not more than 26 days, and probably in a much shorter period. It fell from 10^m.5 to <14^m.0 in not more than 28 days, and is now the N component of a double star distance 7".2, pos. angle 180°, magnitudes 15^m.5 and 15^m.3, situated close S.P. the 9^m.5 star B.D. +56° 436. See *A.N.*, 4545, 4555, 4562, 4564, 4585, 4623; *M.N.*, lxxiii. p.75.

Var. 21, 1912.—A sudden increase in brightness to 13^m.5 appears to have taken place in this object about 1912 January 9. It is now estimated to be about 16^m.5. The 121 plates covering 87, 1911 are available for its photographic analysis, but, although frequently looked for with the 15-inch since 1912 March 7, it has not come within reach of this instrument. *A.N.*, 4564, 4623.

Var. 28, 1912.—This is a variable having a period of about 15 days with a photographic range of 11^m.0 to 13^m.7 and visually 11^m.3 to 14^m.0. It has a companion distance 13" at pos. angle 290°, magnitude 14.5. It can be studied on 107 plates, and has been visually observed on 35 nights. It is particularly interesting by reason of its sparkling bluish white colour near maximum,

which marks it as entirely different from the other faint variables so far observed, and, in view of the existing lack of knowledge concerning the origin of novæ, it is being watched with particular interest. See *A.N.*, 4592, 4623; *M.N.*, lxxiii. p. 78.

Var. 36, 1912.—This is a star varying photographically from $10^m.8$ to $13^m.5$ in a period of about 350 days. The last maximum occurred on 1912 November 29, when it rose visually to $9^m.4$; its colour near maximum is very red. See *A.N.*, 4623; *M.N.*, lxxiii. p. 79.

Two more new variables near $+49^\circ 929$ and $+62^\circ 116$ are also now under observation.

The fainter portions of the Great Nebula in Orion in the neighbourhood of the ι group have been studied by means of long exposures with the reflector, and the existence established of extensions of the nebula which appear to have escaped observation up to the present; also of a large faint nebula between H. IV. 33 and ι Orionis. Absence of dry dark nights has, however, prevented the completion of these observations.

A very considerable amount of material relating to known variables and novæ is being collected, but has not as yet been discussed.

Much time has been spent in perfecting the details of the instruments and in studying the effect of the minutiae of instrumental adjustments and of focussing, etc., on the perfection of the photographic results; and the general conclusion has been arrived at, that if, for special purposes—*e.g.*, dividing double stars—the photographic images are required to bear examination with powers commensurate with those employed normally for visual observations—*e.g.*, up to 16 diameters—the photographic plate, in so far as it is able to record at all, is even more critical than the eye in discriminating the slightest instrumental imperfections, and much more sensitive to atmospheric conditions.

Observations have been possible on 102 nights since 1912 January 1, but the year as a whole has been characterised by an absence of really satisfactory observing weather.

The position of the Observatory from the Ordnance Survey map is $0^\circ 2' 28''$ E., $51^\circ 17' 50''$ N. Height above sea-level 710 ft.

Mr. Newbegin's Observatory, Sutton, Surrey.

The year has been excessively cloudy and trying for observation.

Prominences have been searched for on 65 occasions: of these 31 yielded no result, and the remaining 34, 60 results, thus giving a mean daily average of .92 per observation. The quality of the prominences was poor and uninteresting, the loftiest being $85''$ of arc.

27 were bright

33 were faint

On S hemisphere	46	were recorded
„ N „	14	„ „
„ E limb	31	„ „
„ W „	29	„ „

Small spots and groups have been observed on six occasions, principally in the southern hemisphere.

Rousdon Observatory, Devon.

(Sir Wilfrid Peek's, Mr. C. Grover, Observer, in charge.)

The building is in good repair, and the equatorial telescope and transit instrument are in perfect order. Weather has been most unfavourable, and observations have only been possible on 105 nights. There has been much cloudy sky, and during a part of July and nearly the whole of August a thin film of white haze covered the sky with remarkable persistency, and the stars looked large and nebulous. The four best observing months were March, April, September, and October. Observations of the long-period variable stars with the 6·4-inch Merz refractor equatorial were continued exactly as in former years, and 300 magnitudes were recorded, making a total of 11,769 magnitudes during the twenty-seven years this work has been in progress.

The Lunar Eclipse on April 1 was well seen; although only a small part of the Moon was covered, the outline of the shadow was much sharper than usual, and the shadow more dense, and the lunar features covered were completely obscured, so that at 10 P.M. even the conspicuous Crater Tycho was quite invisible with the equatorial telescope.

The Solar Eclipse on April 17 was observed under most favourable weather conditions. At the greatest phase, ten minutes after noon, when less than one-tenth of the Sun remained visible, a perceptible gloom came over the landscape, and the sky southward over the English Channel was a dull purple. The shadows of the Sun cast by the trees on the ground showed a multitude of little crescents, with the horns pointing to the north, the reverse of the Sun as seen near the meridian. In the telescope the slender horns were exquisitely sharp, and no spots were seen on the Sun.

The near approach of Jupiter to ω Ophiuchi on September 15 was well seen. At 7.20 G.M.T. the star followed the planet at a distance of about one-third the diameter of the disc; it was well defined, and a full magnitude brighter than either of Jupiter's satellites. At 8.20 G.M.T. the star was much nearer the planet, which was very low on the south-west horizon.

Gale's Comet (1912a) was observed here on October 3 at 7.30 G.M.T. very low over the south-west horizon; it rapidly moved northward, and when passing α Serpentis on October 11

was faintly visible to the naked eye. With the telescope it showed a strongly condensed nucleus and a distinct tail of about one degree. The brightness slowly diminished, and by the end of the year it was a large and diffuse nebulosity, with very slight central condensation.

The Rev. T. E. R. Phillips's Observatory, Ashted, Surrey.

During the year 1912 systematic observations were made of the planets Mars, Jupiter, and Saturn, and also of double stars. The 8-inch Coleman telescope, kindly lent by the Council of the Society, has been used for the measurement of a number of pairs in Struve's *Mensuræ Micrometricæ*. The results have been communicated to the Society.

Mr. Reynolds' Observatory, Harborne.

The 28-in. reflector has been employed throughout the year on an investigation into the nature of the spiral nebulae, based on a provisional hypothesis which was given in the May number of the *M.N.* The methods employed were:

1. Direct photography, with a graduated series of exposures.
2. Photography with a double image polarising prism.
3. Spectrography with a prismatic camera.

*Khedivial Observatory, Helwân.
(Director, Mr. B. F. E. Keeling.)*

As no report for 1911 was published in the *Monthly Notices*, the present summary covers the work of that year as well as that of 1912.

Reynolds' Reflector.—During 1911 the telescope was used by Mr. Knox Shaw on 130 nights, 170 plates being exposed; whilst during 1912 the telescope was used on 60 nights, 58 plates being taken. Of the 228 plates 52 were on nebula fields, 40 on J VIII, 81 on comets, 25 on magnitude fields, and 2 on Nova Geminorum.

The J VIII plates of 1911 were sent to the Royal Observatory, Greenwich, for reduction, those of 1912 being reduced at Helwân. The magnitude plates, consisting of two half-hour exposures on a southern and a standard field, have been sent to Greenwich.

Considerable alterations have been made in the telescope. The clock has been re-fitted, and has been provided with an electrical control made by Mr. Hankins in the Observatory workshop. A new "flat" made by Professor Ritchey was mounted in April 1911.

Mr. W. W. Astor has placed at the disposal of the Observatory a sum of money for the purchase of a new 30-inch mirror, which has also been ordered from Professor Ritchey. The telescope was out of action during the second half of 1912, as the driving worm and sector, which had been found to have considerable errors, were in the hands of Sir Howard Grubb for re-cutting.

A prismatic camera by Zeiss, consisting of an objective of 60 mm. aperture and 400 mm. focal length, and a 50° prism, both of ultra-violet glass, has been attached to the telescope.

Time-Service.—The time-service has been maintained as usual. Transits are now taken weekly, this being found sufficient, with the Rietler clock, to ensure that the error of the adopted time is not greater than $0^s.5$.

Gravity Survey.—The value of g has been determined by Mr. Curry at stations along the Nile valley. The pendulum apparatus used in Captain Scott's first Antarctic expedition was lent by the British Government. The observations have been reduced, and the results will be published shortly. The anomalies are very small.

Geodesy.—The primary triangulation has been continued.

The longitudes of four stations in the coastal region west of Alexandria were determined telegraphically by Mr. Wade and Mr. Knox Shaw.

Latitude observations made at Helwân over a period of two years have been discussed, and the results published.

Mr. Curry and Mr. Wade have carried out a detailed comparison of the geodetic differences of longitude on an east and west line across the Nile valley with the corresponding astronomical differences. Large anomalies were found over a distance of 2 or 3 kilometres, and further work is to be carried out with a view to discovering their cause.

Publications.—The publication of bulletins of the astronomical work of the Observatory has been commenced. Up to the end of 1912 seven had been issued. A memoir by Mr. Knox Shaw on the observations at Helwân of Halley's comet has also been published.

The Dominion Observatory, Ottawa.
(*Director, Mr. W. F. King, Chief Astronomer.*)

Astrophysics.—The 15-inch telescope has been principally employed as heretofore in connection with a one-prism spectrograph in radial velocity determinations. 558 stellar spectra have been secured during the year, most of which are measured and reduced. This is considerably fewer than the average (over 800) of previous years, mainly due to the abnormally bad astronomical weather of the past six months.

From these and previous measures the orbits of 4 spectroscopic binary stars have been determined, and further observations of

some previously published orbits were obtained and discussed. This brings the number of orbits obtained at Ottawa to 24 out of a total of about 100.

A number of spectra of Nova Geminorum No. 2 were obtained and measured. The results were published in the *Journal of the Royal Astronomical Society of Canada*, vi. p. 27.

In the beginning of the year a 5-inch plane grating, ruled 15,000 lines to the inch by Dr. Anderson at Johns Hopkins, was obtained. This grating gives strong concentration in the first order at one side, and is mounted in a stellar spectrograph of the supported box type constructed in the Observatory workshop. Comparative tests with the three- and one-prism Ottawa spectrographs show that, though weaker than expected, the grating spectra are remarkably uniform in intensity between H_{β} and $\lambda 3850$, and compare favourably with the prismatic spectra below $\lambda 4300$ and $\lambda 4000$ respectively.

The 8-inch Brashear camera, formerly attached to the equatorial telescope, has been separately mounted. Two additional objectives, a 6-inch Brashear and a Zeiss Tessar, f. 3.5 of 12 inches focus, are, with a 5-inch guiding telescope, attached to the same multiple tube. Objective prisms of 8-inch aperture and of angles 15° and 25° can be attached separately or together, if desired. It is expected that the building to contain it will be completed and the telescope brought into use in the early spring.

The spectroscopic determination of the solar rotation has been actively prosecuted during the year. Two series of plates—one at the special region $\lambda 5600$, and one at the general region $\lambda 4250$ —were obtained. 25 spectra at each of eight latitudes in the green, and at each of six latitudes in the violet, have been selected for measurement. The measurement, reduction, and discussion of the rotation plates obtained in 1911 have been completed, and the results are being published. The 1912 series in the green has been measured and reduced, and the values obtained agree closely with those of 1911.

Department of Geophysics.—This branch of the Observatory comprises Seismology, Terrestrial Magnetism, and Gravity. For the equipment of the first there are two Bosch photographic horizontal pendulums, and a Spindler & Hoyer vertical seismograph with 80 kg. steady mass and mechanical registration. For the second there are Tesdorpf and Cook magnetometers, a Toepfer earth-inductor, besides several dip-circles. For the last there is a Mendenhall half-seconds pendulum apparatus with the Hayford-Fischer interferometer for the measurement of the flexure of pendulum supports.

Bulletins are issued every month of the earthquakes recorded at the Observatory, and sent to 67 of the principal earthquake stations throughout the world. During the calendar year 95 earthquakes were recorded. For the convenience of computing the distances to the epicentre, tables were computed and issued for the principal earthquake stations. For the study of microseisms

an "undagraph" has been ordered from the Cambridge Instrument Company, to be mounted on the exposed Atlantic coast. For the interpretation of seismograms the records of the Cambridge electric thermograph, Fuess anemograph and Shaw-Dines micro-barograph are also utilised.

Two Mainka seismographs have been ordered:—one for the Atlantic coast, the other for the eastern slope of the Rocky Mountains.

An international station has been established at Winnipeg for the study of the deformation of the Earth by the Moon and Sun.

The Observatory has undertaken the magnetic survey of the whole of Canada. During the season of 1912 some 65 stations were occupied in eastern Canada, and the three elements declination, inclination, and horizontal intensity determined. The stations average 25 miles apart. The stations already occupied cover in longitude from 57° to 124° W. or 67° .

Similarly a gravity survey of Canada is being undertaken, and a few stations have already been occupied.

Meridian Circle.—Observations have been continued during the past year on a special list of stars comprising mainly those which have been used for latitude observations throughout Canada in recent years. Work on this list was begun in 1911, and such additional stars have been added from time to time as were being used in the field observations. The transit observations were made with a hand-driven registering micrometer, in conjunction with a reversing eyepiece. On nearly all stars twenty contacts were observed, the apparent direction of motion being reversed in the middle of the observation of each star by means of the reversing prism. Exactly the same method of observation was followed in the case of azimuth stars, except that in many cases less than the usual number of contacts was observed. In zenith distance the usual number of bisections was four, two in each position of the reversing eyepiece. The list of the *Berliner Jahrbuch* was taken as fundamental.

The number of observations obtained during the year, excluding broken nights, was slightly under 2000 in each co-ordinate; the weather, especially during the autumn and winter months, was the worst experienced for years.

Time-Service.—A time-service is maintained in the principal Government offices in the city, consisting of a number of electrically operated dials which are all controlled by a mean time primary clock at the Observatory. In each of the buildings in which dials are operated there is situated a pendulum clock continuously synchronised from the Observatory; each of these clocks operates the dials in its building once every minute by means of a local battery. The total number of dials in use is about 300.

Time-signals are sent out every day at noon (except Sundays and holidays) to the Great North-Western Telegraph Company;

the whole operation of switching the telegraph line into circuit, sending out the signals, and again disconnecting the line, is performed automatically by the signal clock. The latter also operates a circuit which drops a time-ball on Parliament Hill as a signal for the firing of the noonday gun. There is in addition an arrangement by which the beats of a sounder operated by the clock can be sent out over the telephone to anyone requiring exact time.

Field Observations.—The astronomical co-ordinates of three stations in northern British Columbia were measured. Latitudes were determined by Talcott's method, stars from a miscellaneous list being used; these have all been placed on the observing list of the Meridian Circle. For the longitudes the base station used was Field, B.C., whose longitude had been previously determined from Ottawa; the relative personal equation of the observers engaged was determined at Ottawa before the field observations were made. For the determination of clock-correction registering micrometers were used, the telescope being reversed in the middle of the observation of each star. The star-places of the *Berliner Jahrbuch* were used.

Kodaikānal and Madras Observatories.
(Director, Mr. John Evershed.)

The entire equipment of the Poona Observatory was transferred to Kodaikānal during the year, and the work of erecting the Cooke telescope and adapting the newly acquired instruments for research work in various directions has occupied a large amount of time. Meanwhile, the usual routine work of the Observatory has been maintained with very slight interruption.

Photoheliograph.—Direct photographs of the Sun on a scale of 8 inches to the diameter were taken on 329 days. In September the Dallmeyer photoheliograph was dismantled, and the north dome equatorial, fitted with the Poona 6-inch photo-visual object-glass, was brought into regular use for this work.

Spectroheliograph.—Monochromatic photographs of the Sun's disc in "K" light were taken on 331 days, and prominence plates on 280 days. With the auto-collimating spectroheliograph H α images were secured on 158 days. The prominence plates are measured as soon as obtained, and the results tabulated. Duplicates of the disc plates have been sent to South Kensington for measurement, as in former years, and in exchange prominence plates have been received from South Kensington.

Mr. Royds has made a special study of the absorption markings shown on the H α plates.

Grating Spectrograph.—Owing to the paucity of sun-spots, only a few spectra were obtained for the study of radial movements. The general state of calm in the solar atmosphere was,

however, specially favourable for other lines of research, and a large number of comparison spectra were obtained of the Sun's limb and the centre of the disc. The relative displacements of the lines towards the red at the limb have been measured and compared with the displacements due to pressure. A series of plates has also been obtained of the arc spectrum of iron in air and the centre of the Sun's disc. These have been measured to determine the general displacement of the solar lines after correction for the Earth's movements. The general result of the whole investigation, although far from being completed, appears to throw great doubt on the usual interpretation of the line displacements, which ascribes the general shift of the solar lines, as well as the relative shift of the lines at the limb, to the effect of pressure. The investigation is being continued with the aid of a special device for the direct photographic comparison of the solar and arc spectra, and a second series of plates has been obtained with the arc under reduced pressure.

6-Inch Telescope and Spectroscope.—Visual observations of the prominences and spot spectra have been continued as in former years. In October the telescope and its mounting were removed from the south dome, and re-erected in the photoheliograph dome: this involved a break in the observations for one week only. The Poona refracting telescope, to which a very powerful grating spectroscope has been adapted, was erected in the south dome.

Special attention is now being given to the detailed observation of metallic prominences, and of prominences showing displacements of the hydrogen lines. It has been found that not only do prominences in general show a numerical preponderance on the east limb, but the preponderance is much greater in the above-mentioned special classes of prominence. As the metallic prominences are closely associated with sun-spots, this appears to indicate that both sun-spots and prominences are more active on the east than on the west limb.

Poona 20-Inch Reflecting Telescope.—Plans have been prepared and a site chosen for a new building to accommodate this telescope.

Publications.—Bulletins Nos. XXV. and XXVI., dealing with the prominence observations for 1911, were published during the year; and Nos. XXVII., XXVIII., and XXIX. were sent to press towards the end of the year. The titles of these are: "On the Presence of Radium and the Elements of the Inactive Group in the Chromosphere," "On the Relative Numbers of Prominences observed on the Eastern and Western Limbs," and "Summary of Prominence Observations for the first half of 1912."

The meteorological and seismological observations were continued as in former years.

At Madras astronomical work was confined to the maintenance of the time-service.

Adelaide Observatory, South Australia.
(Director, Mr. G. F. Dodwell.)

During the year the transit circle telescope was mainly utilised for the observation of clock stars for the time service. The time-ball at the semaphore was dropped daily at 1 p.m., except on Sundays and on a few occasions when telegraphic communication was interrupted. The ordinary system of distributing time-signals throughout the State was continued, and an attempt was made to bring various public departments and business establishments in the city into direct connection with the Observatory for time standardisation, but the attempt has failed for the present owing to an insufficient demand for the service.

A list of the *étoiles de repère* in the zone -20° to -30° was received from Professor Perrine of Cordoba, also the fundamental star list from the Bureau des Longitudes. Until the official list of intermediates is available, however, it has been thought inadvisable to commence systematic observations in this zone. In the meantime, a suggestion having been received from Mr. W. E. Cooke with regard to co-operation in observing stars in the Sydney zone -52° to -64° , preliminary work has been commenced in carrying out the suggestion. The investigation of the division errors of the circle is also in progress. The impersonal micrometer, which has been attached to the transit circle for recording star transits, has proved a success, the personal equation between the observers having been reduced to a very small quantity.

A proposal to determine the western boundary of this State (the 129th meridian of east longitude) has been dropped by the Government for the present, and this work will probably not be carried out until the transcontinental railway line to Perth, now in progress, has been completed.

An investigation of almucantar observations made at the Boundary Obelisk on the 141st meridian and at Adelaide and Sydney has been made, and a paper on the subject sent to the Australasian Association for the Advancement of Science.

The eight-inch Cooke equatorial has been used for miscellaneous observations, and its use has been offered on certain nights to members of the South Australian Astronomical Society, who wish to undertake certain lines of work. Some of the members have availed themselves of this offer, and drawings of Jupiter during the opposition and observations of long-period variable stars have been made. It is anticipated that the encouragement and development of amateur work in this and other directions will produce good results.

The library has been rearranged, and is undergoing a reclassification. In this connection it is desired to record a grateful appreciation of the donation by the Council of the Royal Astronomical Society of a very valuable set of their *Memoirs* and *Monthly Notices*.

The Milne seismograph has been continuously at work during the year, and tabulated records have been sent to Professor Milne.

Public visits have been made to the Observatory on practically every Friday evening during the year, and occasional lectures on astronomy have been given at country institutes.

An extensive series of observations of the physical appearance of Jupiter with drawings, made principally by the late Mr. E. P. Sells and hitherto unpublished, has been sent to the printer and is partly printed.

Perth Observatory, Western Australia.
(Acting-Director, Mr. H. Burnham Curlewis.)

Meridian Observations.—The observations and reductions of zone stars between 37° and 39° were completed and are in course of preparation for the printer. This will form vol. vi. of the Meridian Catalogue, and will complete the list of *étoiles de repère* for zones 31° – 41° . Vol. v. was distributed during the year.

Before making a start on the “intermediates” prepared for the new international meridian scheme, it is proposed to collect and discuss the results of “intermediates” taken in course of the zone work, and also to determine some very necessary instrumental errors of the transit-circle.

Astrographic Catalogue.—Mr. Nossiter, who is in charge of this section of the work, reports as follows: “I have the honour to report that during the year 1912 satisfactory progress was made with the astrographic work.

“303 plates were taken as follows:—

Catalogue plates	.	.	.	268
Pritchard regions	.	.	.	35

Of the Catalogue plates 53 were rejected owing to various defects, and the remainder were passed for measurement.

“Owing to the London Dock Strike it was impossible to obtain plates for some time, and consequently several plates were unavoidably missed and will be taken next year.

“In accordance with a promise made to the Edinburgh Observatory, 110 plates in zone -38° were forwarded as soon as taken.

“In all, 98 plates have been measured during the year, containing 31,160 stars.

“Two volumes (i. and iv.) of the Astrographic Catalogue were printed and distributed in the early part of the year, and another vol. (ii.) was in the printer’s hand. This last volume has since been completed, but is not yet distributed. The manuscript of vol. iii. was sent to the printer early in January, but at the end of the year the printing was not completed.

“In view of the length of time taken by the printer in the produc-

tion of these volumes and the fact that the Observatory allowance for printing was not a large one, it was decided not to push on too rapidly with publication. However, two more volumes of the plate measures are ready, and will be sent to the printer as soon as he has completed the volume in hand."

Miscellaneous.—The time-service has been maintained as usual. The time-ball at Fremantle was dropped daily at 1 p.m., with the exception of a few occasions when faults occurred on the line. During the latter end of the year it was deemed advisable to keep a daily automatic record of the time of ball drop as a check on its accuracy.

The number of visitors has been even more than usual, especially during the last few months of the year, and the staff has experienced considerable difficulty in coping with their demands.

A continuous record of Earth tremors has been kept on the Milne seismograph, and the results forwarded to the Secretary, British Seismological Society, for publication.

The final computations of the Fremantle tides for 1908, 9, 10, and 11 were completed, and the results sent to the U.S. Geodetic Survey to obtain predicted tide tables. The preliminary compilation of 1908 records from Port Hedland, on the N.W. Coast, have also been finished.

A partial eclipse of the Moon was observed on September 26, and Gale's Comet was also under observation when weather permitted.

In August Mr. Cooke resigned his position as Director, to take up a similar position in New South Wales.

The following is a résumé of the work done during the year:—

Plates completely measured in direct and reversed positions	98
Number of stars measured	31,160
„ „ Catalogue plates passed	212
„ „ Pritchard „ „	35
Nights on which time was determined	208
Observations of zone stars in R.A. between January 8 and July 18	2780
Observations of zone stars in N.P.D. between January 8 and July 18	2780
Separate determinations of collimation error	12
„ „ level error	106
„ „ azimuth error	92
„ „ nadir point	82

The Acting Director wishes to place on record his appreciation of the meritorious way in which the staff has worked during a period which, from one cause and another, would have damped the enthusiasm of officers less keen and conscientious.

Sydney Observatory. (Director, Mr. W. Ernest Cooke.)

This Observatory had been without a Director since the death of Mr. H. A. Lenehan in May 1908 until August 1912, when Mr. W. E. Cooke, Director of the Perth Observatory (W.A.), was appointed Government Astronomer of New South Wales and Professor of Astronomy in the Sydney University. Owing to the rapid growth of Sydney, the present site of the Observatory has become unfit, and the instruments are not suited for the exacting requirements of modern astrometry. It has therefore been determined to move the entire institution to a new site, and to provide some new instruments and remount others. In particular, a new meridian instrument of modern design, suitable for fundamental work of the highest precision, will be provided, in accordance with the recommendation of the Paris Astrographic Congress of April 1909.

Meanwhile, the routine work has been almost stopped for the present, and preparations for the reorganisation have been commenced.

Mr. Tebbutt's Observatory, Windsor, New South Wales.

The only astronomical work done at this Observatory during the year 1912 was the observation of Comet (Gale) 1912 with the eight-inch equatorial. Measures were made with a square bar micrometer on nine evenings, September 10-22. The results have been published in *A.N.*, 193, p. 314. The only other observations were those of the daily rainfall, and of the maximum and minimum shade temperature and solar radiation for each month. The rainfall record now extends over fifty years, namely, from 1862 December 31 to 1912 December 31, the mean annual result being 30.613 inches.

*Union Observatory, Johannesburg.
(Union Astronomer, Mr. R. T. A. Innes.)*

This observatory appears in previous years as the Transvaal Observatory. When the union of the four colonies of South Africa took place, the two observatories maintained by the Colonial Governments (the Transvaal Observatory at Johannesburg and the Natal Observatory at Durban) and the four meteorological services of the four colonies passed under the control of the Minister of the Interior. It was decided that a separate meteorological branch should be formed as from 1912 April 1 under the Minister for Lands. Mr. Nevill retired from the Natal Observatory on pension in March, and Mr. Hodgson, his chief assistant, died a few weeks earlier; and the Government decided to close the observatory at

Durban. The fine 8-inch Grubb refractor there with its accessories has been accepted by the Corporation of Durban; the 4-inch refractor has been loaned to the Natal University College at Maritzburg.

The Transvaal Observatory was then re-named the Observatory of the Union of South Africa, and the officer in charge the Union Astronomer. Three assistants were transferred to the new meteorological branch; amongst these was Mr. G. W. Cox, who had measured a considerable number of double stars.

The Union Observatory is to maintain its first-order meteorological station, which, it is believed, is the only one of its kind in the Union at the moment. Daily records are telegraphed to the Meteorological Services at Bulawayo, Capetown, and Lourenzo Marques.

The changes referred to above caused an interruption to the usual work of the Observatory.

Instrumental Equipment.—During the year this was increased by the arrival of the Zeiss stereo-comparator. Several trials indicate that star and planet places can be quickly measured with an accuracy equal to that of meridian observations. It is hoped to publish a description of this instrument in the course of the next twelve months. The building for the 26-inch refractor is practically ready to receive the telescope, but the glass disks for the lenses have not yet been cast.

Circular No. 13 of the Transvaal Observatory and No. 1 of the Union Observatory were distributed in 1912, and Nos. 2 and 3 are in print.

9-inch Refractor.—Measurements of double stars commenced in 1911 were continued. Measures of 213 pairs (5 new), of which 56 are less than 1''·0 distance, will appear in Circular No. 4. The phenomena of Jupiter's Galilean Satellites were numerous observed. It is satisfactory to record that these observations made here since 1908 are to be compared both with Dr. de Sitter's theory (*Proceedings, Amsterdam Academy*, March 1908) and Professor Sampson's Tables. Dr. de Sitter is carrying out the comparison with his theory, whilst Mr. Gutesmann of the Bureau des Longitudes, Paris, is making the comparisons with the tables.

All comets while south of the Sun's declination were observed when possible with both the 9-inch refractor and the Franklin-Adams star camera. The results have been published in either the *Astronomische Nachrichten* or the observatory circulars. The ephemeris for the expected return of Holmes's Comet was not sent direct to the observatory, and in consequence the Comet was not looked for until too late. The observatory staff is too small to let it look for work, but especial attention is always given to requests sent us for observations.

Latitude observations (2 $\frac{3}{4}$ -inch telescope) have been maintained by Messrs. Worsell, van der Spuy, and Simpkins under the direction of Mr. W. M. Worsell. Dr. Albrecht has published the observations made between 1910 March 22 and 1911 November 13 in a supplement to the report of the International Latitude Service.

All the Franklin-Adams charts of the southern hemisphere with two exceptions have been obtained and transmitted to the Astronomer Royal. Other long-exposure plates, after partial examination here, have been sent to Mr. Hinks, to aid him in his researches on the distribution of nebulae.

This observatory has been asked to assist in the regular observation of minor planets by taking charge of the zones south of -9° Dec., and numerous plates have been taken by Mr. H. E. Wood. As quickly as these plates can be measured, the results are published. In addition to a crop of new minor planets, measures of the interesting planets Eros, Nestor, Achilles, and Hector were obtained; and also, on plates of 1911, some measures of MT. Orbits of several new planets have been calculated by Mr. Wood.

The time-service has been extended to Natal. One of the mean time clocks from the Natal Observatory has been put up in the Telegraph Department of the Durban Post Office as a reserve; but in ordinary course, the signal from the Observatory drops the time-ball on the Bluff at noon.

Seismological observations have been continued on the usual lines.

Lovedale Observatory, South Africa.
(*Dr. Alexander W. Roberts.*)

The work at this observatory has been confined almost exclusively to variable star work.

During 1912, 3012 observations were secured, chiefly of long-period stars.

Towards the close of the year, through the very great kindness of Professor Pickering, the observatory received on loan the 4-inch Harvard meridian photometer. It is proposed with this instrument to make a careful determination of the brightness of the comparison stars used, especially these used for estimates of the variation of Algol stars.

A grant of £100, also, has been secured from the Royal Society of South Africa for the construction of a photometer of a new design.

It is hoped to have the meridian photometer and the new photometer both in service in 1913.

NOTES ON SOME POINTS CONNECTED WITH THE PROGRESS
OF ASTRONOMY DURING THE PAST YEAR.

Discovery of Minor Planets in 1912.

Seventy-nine new planets were discovered or first announced
in 1912.

Letter and Number.	Date. 1911.	Discoverer.	Letter and Number.	Date 1912.	Discoverer.	Letter.	Date. 1912.	Discoverer.
MF ^a	June 23	L	OG	Mar. 9	Be	PJ	Oct. 4	Wd
MF ^b	29	Wd	OG ^a	13	Me	PK	Sept. 8	Wd
MF ^c	29	Wd	OH	19	Be	PL	Nov. 6	K
MF ^d	29	Wd	OJ	19	Be	PM	7	K
MF ^e	29	Wd	OK 730	Apr. 10	P	PQ	June 8	Me
MF ^f	29	Wd	OK ^a	11	Me	PR	11	Me
MF ^g	July 19	Wd	OL	12	K	PS	19	Me
MT ^a	Oct. 13	I, Wd	OM	12	K	PT	July 3	Me
MZ ^a	18	I, Wd	ON	12	K	PU	5	Me
NK	Nov. 15	I, Wd	OO	13	K	PV	Aug. 17	Me
NK ^a	15	I, Wd	OP	13	K	PW	Dec. 8	K
NK ^b	15	I, Wd	OQ 731	15	Ma	PX	8	K
	1912.		OR 732	15	Ma	PY	9	V
NO	Jan. 8	Wf	OS	17	K	PZ	Nov. 16	Me
NR	19	H	OT	17	K	QA	30	Me
NT 727	Feb. 11	Ma	OV	19	Wd	QB	Dec. 7	Me
NU 728	16	P	OW	19	Wd	QC		
NV	Jan. 12	Ba	OX	19	Wd	QD		
NW	16	Wd	OY	19	Wd	QE		
NX	Feb. 8	Be	OZ	19	Wd	QF		
NY	9	Be	PA	May 7	Be	QG		
OA	Jan. 13	Me	PB	7	Be	QH		
OB	13	Me	PD	15	Wd	QJ		
OC	24	Me	PE	18	Wd	QK		
OD 729	Feb. 9	Me	PF	Sept. 16	Wf	QL		
OE	10	Me	PG	Oct. 4	K	QM	Dec. 31	K
OF	13	Me	PH	11	P			

The initials stand for:—Ba = Prof. Barnard (Yerkes); Be = S. Beljawsky (Simeis, Crimea); H = Herr Helffrich (Heidelberg); I = Mr. Innes (Johannesburg); K = Herr Kaiser (Heidelberg); L = Mr. Lampland (Flagstaff, Arizona); Ma = Herr Massinger (Heidelberg); Me = Dr. Metcalf (Winchester, Mass.); P = Dr. Palisa (Vienna); V = Herr Voigt (Heidelberg); Wf = Prof. Wolf

(Heidelberg); Wd = Mr. Wood (Johannesburg), assisted in several cases by Mr. van der Spuy.

The following planets, not numbered at the date of the last report, have since received numbers: LX 715, MD 716, MJ 717, MS 718, MT 719, MW 720, MZ 721, NA 722, NB 723, NC 724, ND 725, NM 726.

The following identities have been established:—36 = 1912 OU; 81 = 1908 FK; 94 = 1912 PP; 209 = 1912 PN; 211 = 1912 NP = NQ; 243 = 1910 JP; 289 = 1912 PO; 395 = 1911 ME; 438 = 1912 NS; 530 = 1911 MN; 565 = 1912 NZ; 577 probably = 1912 NV; 608 = 1911 ML; 716 = 1906 UN^b; 721 = 1911 NH; 723 = 1903 LJ; 727 = 1900 FE = 1908 CV; 1901 GX = 1906 UT = 1909 GF (re-observed 1912).

The following planets have been named:—578 Happelia, 594 Mireille, 605 Juvisia, 711 Marmula, 715 Transvaalia, 716 Berkeley, 718 Erida, 719 Albert.

The planets of the Trojan group, Hector, Achilles, and Nestor, have all been photographed at Johannesburg in 1911 or 1912.

There was a remarkable recovery of the planet MT, now numbered 719, whose discovery and loss were described in the last report. From the three observations given there, two orbits were found, one by Professor Franz, the other by Messrs. Haynes and Pitman, who used Leuschner's short method. Their resulting orbit is a good testimony to the value of the method, for by the aid of their ephemeris Mr. Davidson found three images of the planet on plates taken with the 30-inch reflector at Greenwich on 1911 October 11. Subsequently images were also found on Heidelberg plates of September 16 and October 17, and a probable one on a Johannesburg plate of October 18. There is also a possible image on a Lick plate of October 26, but this is inconsistent with the images of September 16, October 17, 18. Either it or they do not belong to MT. The balance of evidence is clearly in favour of the first orbit below (satisfying the greater number of days); but as the matter is not quite free from doubt, it will be well to examine both positions when a favourable opposition recurs. Both the following orbits are by Mr. Haynes, for the Equinox of 1911'0.

Range of observations. T in G.M.T.	1911 Sept. 16 to Oct. 18. 1911 Aug. 29'1322	Oct. 3 to 26. Aug. 30'6334
ω	152° 0' 27"	153° 15' 27"
Ω	185 32 38	185 25 51
i	10 47 36	8 51 34
ϕ	32 31 32	24 15 5
e	0'537675	0'41074
μ	862''·248	1292''·7
$\log a$	0'409583	0'292354
q	1'18722	1'1552
Period (years)	4'11505	2'7449
Aphelion distance	3'94864	2'7656

It will be seen that the eccentricity of the first orbit is extraordinarily great, the aphelion distance being only one unit from Jupiter's orbit, so that the orbit would be subject to considerable perturbations. L. v. Tolnay has published an orbit nearly identical with the first orbit above. His period is 15 days longer, being 4.15641 years. His orbit gives residuals of over 6" to the Greenwich photographs of October 11; these are considered inadmissibly large, considering the large scale of these photographs and their fair definition.

The magnitude of the planet in aphelion is only 19, and it will probably only be visible near perihelion. This will be in 1915 according to the first orbit, in 1914 according to the second. The diameter of MT is probably about 3 miles.

It is of interest to note that planet 1908 DW, also discovered by Dr Palisa, has an orbit not unlike that of MT. The following elements are from *Berliner Jahrbuch*, 1913:—

T 1908 June 27.7, ω 129° 27', Ω 178° 12', i 6° 17', e 0.4575, period 4.3345 years, q 1.442.

MF^d appears to have a very eccentric orbit: epoch 1911 July 20.5, M 353°, ω 22°, Ω 289°, i 12°, ϕ 20°, μ 742".

Professor Strömgren has published two papers on minor planets, one a revision of the orbit of 624 Hector, for which he finds $\mu = 293''.1072$, the other a method of approximate perturbations illustrated by the case of 24 Themis; Dr. M. Brendel also gives a method of approximate perturbations in *Astr. Nach.*, 4559.

The planet Lutetia made a near conjunction with Jupiter on 1912 June 7, which was observed by Professor Barnard.

A. C. D. C.

The Eighth Satellite of Jupiter.

This Satellite was under observation in 1912 both at the Lick Observatory and at Helwan. Combining the Helwan observations into four groups, they give the following residuals from the ephemeris in *M.N.*, vol. lxxi. p. 50:—

Date.	Tab. - Obs.	
	R. A.	Dec.
1912 March 23	-1.75 ^s	+13.6"
April 22	-2.13	+15.6
May 20	-2.52	+18.6
June 10	-2.57	+18.0

M. J. Trouset gives, in *Comptes Rendus* for 1912 June 24, the results of some calculations by the methods of Delaunay and Andoyer of the inequalities of this satellite. He uses for m (which is mean motion of $\odot \div$ mean motion of VIII.) the value -0.172 . He finds the terms containing $8 \odot$'s anomaly are practically insensible. His theory does not represent the

observations with strict accuracy, but he hopes to correct his coefficients by observation when the satellite has been observed throughout a revolution of Jupiter. He finds that the perijove goes round Jupiter in 300 revolutions of VIII., or 600 years; the node in 40 revolutions of VIII., or 80 years.

Mr. J. Jackson of Trinity College, Cambridge, has also begun some researches on the motion of this satellite. A. C. D. C.

Comets.

After the eight comets of 1911 the year 1912 with three only may be considered somewhat barren. At its beginning six comets of the preceding year were still under observation, but it was not until September that the first new discovery was made.

Comet 1911 a (Wolf) was observed at Algiers till January 25, and is stated to have been of the twelfth magnitude at the middle of the month. *Ast. Nach.* 4607 contains an investigation by M. Kamensky of the motion of this comet at former returns. He finds some discordances in the observation of 1884, which he thinks can be readily explained by a want of symmetry in the comet's shape, but concludes that the comet gives no evidence of any non-gravitational force such as Encke's comet has been thought to do. *Comet 1911 c* (Brooks), which will be remembered as a conspicuous object before travelling into the southern hemisphere, was followed in Chile till January 31. A detailed account of the spectrum of this comet by Mr W. H. Wright is published in *L.O.B.*, No. 209, in which the writer points out its general similarity to the spectra of Halley's Comet, Daniel's Comet (1907 *d*), and the Daylight Comet 1910 *a*. The bands identified by Professor Fowler (*M.N.*, vol. lxx. p. 6) in the spectrum of Morehouse's Comet (1908 *c*) with the bands of "low pressure" and "high pressure" carbon monoxide are strongly represented. *Comet 1911 e* (Borrelly's periodic Comet) was last observed at Algiers on May 8. It was then exceedingly faint, being rated below fourteenth magnitude. Apparently the latest observation of *Comet 1912 f* (Quénisset), which, after being in high N. Declination before discovery, travelled south beyond the reach of northern observers in November, was made in Chile on January 25. *Comet 1911 g* (Beljawsky), which had been a fine naked-eye comet in October, was observed at Cordoba on January 28th, but, as it was stated to be "visible in a large telescope," it is probable that it was then a faint object. *Comet 1911 h* (Schaumasse) was observed at Algiers till after the middle of February. M. G. Fayet found for it elliptical elements bearing a marked resemblance to those of Comet 1894 I. (Denning), but identity seems impossible, as the periodic time in both cases is approximately seven years, and the interval between their perihelion passages about seventeen and a half years. Moreover, as Dr. Cronmelin pointed out (Observatory No. 445, p. 93), if the two

objects were identical, and the major axis had been much altered by perturbations, the period would not now be so nearly the same as formerly. This comet adds one more to the family of Jupiter.

Comet 1912 a.—The first comet of the year was found on September 8 by Mr. Walter F. Gale, who will be remembered as the discoverer of Comet 1894 II. When first seen it was of about the sixth magnitude, and visible to the naked eye. A striking feature of this comet was a double tail, of which the two components were separated by an angle of between 50° and 60° . A photograph taken at the Union Observatory, Johannesburg, on September 13 shows the tail in the form of a fan, the principal streamer being just over 5° in length.

Travelling northwards, the comet became visible in England in October. Telescopically it then showed a large coma with central condensation and stellar nucleus, and the two tails were distinctly visible.

A description of the spectrum by M. Idrac, as observed at Meudon, is published in *C.R.* (No. 194, November 1912), where it is shown that the coma exhibited the ordinary comet spectrum indicative of cyanogen and other carbon compounds. The comet was at perihelion on October 4. The orbit has a high inclination—about 80° , and the comet will be within a few degrees of the North Pole at the end of January.

Comet 1912 b.—This comet was discovered at Nice by M. Schaumasse on October 18, and shown by M. G. Fayet to be identical with Tuttle's Comet. The return was interesting as being unexpectedly early. Without applying corrections for perturbations, Kaplan Niko Miličević, using the instantaneous period of Rahts at the last return, had predicted in his search ephemeris (*A.N.*, 4602) 1913 January 3 for the date of perihelion. The actual passage took place in 1912 October 28, and M. E. Fayet has shown that a shortening of the period by about two months was due to a diminution of the major axis of the comet's orbit, in consequence of perturbations by Jupiter about 1901. This last return is also interesting as being the shortest on record, and Dr. Crommelin has remarked (*Observatory* No. 454, p. 407) that there appears to be a more or less regular wave in the period with a cycle of about 88 years, maxima occurring about 1790 and 1871, and minima about 1817 and 1912. In appearance the comet was a faint telescopic object. It showed a round nebulosity $3'$ in diameter, on October 19, with an ill-defined condensation of magnitude $10\frac{1}{2}$ to 11 towards the centre.

Had perihelion occurred two months later, as expected, the comet would have passed very near the earth at the middle of December, and the return would have been the most favourable since the comet's discovery by Méchain in 1790.

Comet 1912 c.—This, the last comet of the year, was discovered by M. Borrelly at Marseilles on November 2. It was a faint telescopic object of the tenth magnitude and had already passed perihelion on October 20.

The relationship between the η Aquarids of May and Halley's Comet, suggested as probable by Professor A. S. Herschel (*M.N.*, vol. xxxviii. p. 379), seems to be now well established. Mr. Charles E. Olivier (*Astron. Journal*, vol. xxvii. p. 139) gives elliptical elements of the orbit of the meteor swarm (assuming the major axis to be the same as that of the comet) observed on six nights in 1910 and 1911. *Ast. Nach.* 4573 also contains parabolic elements by Cuno Hoffmeister from observations in the same years. The similarity between the two sets of elements and those of Halley's Comet is very striking.

	Ω .	i .	π .	q .	$\log e$.
Olivier .	45°6	162°6	148°6	0.626	9.985
Hoffmeister	45	167.5	147.8	0.610	...
Halley's Comet	57.3	162.2	169.0	0.587	9.984

Mr. Olivier attributes the fact that the agreement is not more complete to the circumstance that none of the meteors he observed was nearer to the actual orbit of the comet than 5,000,000 miles, while some were as far from it as 13,000,000 miles, the effect being to increase the perihelion distance and change the longitudes.

It was thought that the Comet 1892 III. (Holmes), and Comet 1852 IV. (Westphal) might be observed in 1912, though M. Viljev considers the most probable date for the perihelion of the latter to be 1914 April 23, with a probable error of $7\frac{1}{2}$ months. An ephemeris for Holmes's comet was published by Dr. H. J. Zwiers, and ephemerides for Westphal's Comet by Herr Hnatek on various assumed values of the period between 60 and 62 years. Up to the present it appears that nothing has been seen of either comet.

Definitive elements of the orbit of Comet 1910 I.—the bright "daylight comet"—were published in *Ast. Nach.* 4605 by M. S. Mello e Simas. He finds no sensible deviation from a parabola, the elements of the most probable orbit being:—

T	1910 Jan. 17.0946,	Paris M.T.
ω	320° 53' 41"	1910.0.
Ω	88° 45' 54"	
i	138° 46' 56"	
$\log q$	9.110505	

T. E. R. P.

Solar Activity in 1912.

Sun-spots.—The year just past appears to have been that of the sun-spot minimum; the large proportion of days on which the Sun was free from spots, the small numbers and areas of the spots on the days on which any were seen, and the low latitudes which they affected, all point to the same conclusion. In the year 1911 there had been 186 days without spots; in 1912 there were about

250 such days. In 1911 the mean daily area only amounted to 64-millionths of the Sun's visible hemisphere; in 1912 even this low figure had been diminished by more than one-half. In 1911 the number of separate groups observed had been 62; in 1912 there were only some 33.

But in 1912 there was a great change in the distribution of the spots in latitude. During the first eleven months of the year all the spots observed were in low latitudes, and, with very few exceptions, in the southern hemisphere. In December, on the other hand, two groups appeared in the northern hemisphere; the first in N. Lat. 21° , the second in N. Lat. 27° ; the latter being the highest northern latitude recorded since 1908 February 15. The first high latitude spot in the northern hemisphere that appeared in the cycle now drawing to a close was observed in 1901 September 12, so that the opening of the new cycle falls 11.3 years after that of its predecessor. M. Guillaume, indeed, reports from the Observatoire de Lyon that a few faint pores were observed in a high southern latitude, S. 42° , as early as 1912 March 28; but these were very short-lived, and were not shown upon either of the solar photographs taken at Greenwich on that day, and the two completely developed groups in high latitude observed in 1912 December may more fitly be taken as marking the beginning of the new cycle.

None of the spot-groups of 1912 were large; the three most considerable were those of April 8-14, October 5-11, and December 12-22—all in the south equatorial region. Only one of these persisted into a second apparition; that of April 8-14 being seen again, April 30-May 9.

B. W. M.

Prominences.—Owing to the very unfavourable weather conditions during the last 12 months for the photography with the spectroheliograph of the prominences at the limb of the Sun, the record secured at the Solar Physics Observatory, South Kensington, is exceedingly meagre. The observations are unfortunately too few to give even an approximate value of the mean daily frequency for that period.

The only data available at the present time are certain prominence returns which are regularly communicated to the *Indian Monthly Weather Review* by the Director of the Kodaikānal Observatory. The numbers there published indicate a considerable increase in the frequency of prominences from that of the year 1911. These returns, which refer to "large," *i.e.* one minute or more in height, "metallic," and "eruptive" prominences, give the following numbers for the half-yearly periods:—

	Large.	Eruptive.	Metallic.	Days of Obs ⁿ .
1910 Jan.-June	297	19	26	171
July-Dec.	226	24	7	157
1911 Jan.-June	199	35	12	168
July-Dec.	239	33	7	130
1912 Jan.-June	305	18	8	172

In order to ascertain whether the above stated result can be accounted for by a difference in the number of days of observation, the last column has been added. The comparison indicates that there is reason to believe that the large increase in frequency is actual unless due to some advance in instrumental efficiency with which the writer is unacquainted.

The values of the mean daily frequencies as deduced at the Kodaikánal Observatory from full data, both visual and photographic, show that the year 1911 differed little from its two predecessors.

	1905.	1906.	1907.	1908.	1909.	1910.	1911.
North	7·8	8·6	8·9	8·9	10·15	10·4	9·85
South	7·8	8·2	10·7	10·0	10·25	10·3	10·35
Total	15·6	16·8	19·6	18·9	20·4	20·7	20·2

Quite a different deduction can be drawn when the "Mean Daily Profile Areas" are examined. Below are the values from 1906 to 1911.

	1906.	1907.	1908.	1909.	1910.	1911.
North	2·51	1·92	2·41	2·10	2·03	1·27
South	2·17	2·27	2·98	2·04	2·07	1·64
Total	4·68	4·19	5·39	4·14	4·10	2·91

It will be seen that there is a drop of 29·1 per cent. in the mean area from 1910. Comparing the two tables of "frequency" and "area," it will be noted that there is a tendency for increased frequency to be accompanied by decrease in area, and *vice versa*.

W. J. S. L.

Solar Research in 1912.

Sun-spots.—As a guide to further research, Professor Hale has outlined a working hypothesis of sun-spots. An eruption, or some other cause tending to produce rapid convection, gives rise to an upward motion of gases from the interior towards the photosphere. Vortex motion is set up by the difference in rotational velocity of adjoining zones, or by irregularities of structure, and is maintained by convection. The circulation in the vortex is vertically upwards, and then outward along the photosphere. There is a cooling by expansion at the centre of the vortex, and the resulting comparatively dark cloud constitutes the umbra. As in Harker's experiments (*Roy. Soc. Proc.*, vol. 86A, p. 379), there is a rapid flow of negative ions towards the cooler gases at the centre from the hotter gases without, and the whirling of the ions produces a magnetic field. The descending gases (especially hydrogen) in the higher atmosphere of the Sun are drawn in toward the pole of the magnet along the lines of force, and this accounts for the configuration of the hydrogen flocculi shown by the spectroheliograph.

The hypothesis may be extended from single to multiple spots. The polarities of the two principal spots are opposite, and the hydrogen flocculi resemble the lines of force about a bar magnet (*Pub. Ast. Soc. Proc.*, vol. xxiv. p. 226).

The Spectroheliograph.—An account of the changes in a large solar prominence observed on 1911 June 19–20, with numerous illustrations, is given by Dr. Slocum. The prominence finally became dissipated and floated away upwards, in the manner characteristic of most of the prominences which have been observed in their last stages (*Ap. J.*, vol. xxxv. p. 301).

A fine example of the attraction of a sun-spot for prominences is also given by Slocum (*Ap. J.*, vol. xxxvi. p. 265). The photographs reproduced show very clearly that prominence matter from distances as great as 260,000 km. was drawn into the spot with great and accelerated velocities. This agrees with Evershed's observations as to the inflow of the gases of the higher chromosphere, in his work on radial motion in spots, but Evershed found a diminishing velocity as the centre of the spot was approached. The attraction persisted when the spot group had disappeared and only flocculi remained to mark its place.

Investigations as to the relation between prominences observed on the Sun's limb and the dark markings shown on spectroheliograms have been made by Professor Riccò and Dr. Deslandres (*C.R.*, vol. clv. pp. 496, 531). The occurrence of prominences near the same point on several successive days indicates a linear extension along the Sun's surface, and Professor Riccò has determined the corresponding forms by projecting all the prominences observed during a half-rotation on a single chart so as to show their positions at the middle of the period. When points representing the same prominences are connected, they bear a strong resemblance to the filaments and alignments shown in the Meudon high-level (K_3 and $H\alpha$) spectroheliograms. Such differences as are found may be attributed to the fact that the part of a prominence giving the strongest absorption is not necessarily the brightest when seen at the limb. M. Deslandres points out that a precise study of this question is now possible, because the Meudon plates show both the dark markings and limb prominences in the same exposures.

Filaments, it may be recalled, are the very dark markings, while the term *alignement* is reserved for the more numerous and longer linear markings which are much less distinct. Some of the alignments are feebly bright, but usually they show a faint dark line between two feebly bright ones. Filaments are most distinct in hydrogen, but are also seen in calcium, while the alignments are mostly discernible only in the calcium (K_3) images. The brightest prominences show little relation to the filaments, but they often appear where a scarcely visible alignment intersects the limb; the prominence usually takes the direction of the corresponding alignment, and, coinciding with one of the bright edges of the alignment, it appears to be slightly displaced. If a "node," or

intersection of two alignments, comes to the Sun's edge, the corresponding prominence is especially large. This is contrary to the views of Hale and Evershed, who regard the filaments as the projection of prominences on the disc. Deslandres looks upon an alignment as a current in the superior layer, giving rise to prominences when subjected to vertical forces.

In another paper Dr. Deslandres gives further observations which he regards as supporting his view that there is a general magnetic field over the Sun, analogous to that of the Earth, but very much weaker (*C.R.*, vol. clv. p. 1573). The general magnetic field of the Sun has also been discussed by M. A. Perot (*Jour. de Phys.*, series 5, vol. ii. p. 975), and an account of preliminary efforts to observe the corresponding small Zeeman effects has been given by Professor Hale (*Terr. Mag.*, vol. xvii. p. 173).

Solar Rotation.—The chief contribution to this subject during the year was a report by J. B. Hubrecht on his work at Cambridge (*M.N.*, vol. lxxiii. p. 5). In accordance with the co-operative scheme of the Solar Union, the region studied was that between wave-lengths 4300 and 4500. The forty lines selected for measurement included arc and spark lines of iron, titanium, scandium, etc., but no suitable lines belonging to elements of very high or very low atomic weights occurred in the region considered. The results are remarkable as giving an equatorial velocity 7 per cent. lower than that usually found, and in showing no certain systematic deviations from the normal value for any of the forty lines considered. A scheme of exposures was devised so as to give separately the displacements in the two hemispheres, and evidence was obtained that the velocity in the southern hemisphere was slightly greater than that in the northern.

Photographs taken at the Royal Observatory, Edinburgh, have confirmed the solar origin of the oxygen triplet 7772–7775 by proving that the lines are displaced at the limb with respect to neighbouring telluric lines (*M.N.*, vol. lxxiii. p. 31).

From a discussion of recurrent spot groups, Dr. Dyson and Mr. Maunder have made a new determination of the direction of the Sun's axis. The result (for 1850.0) is $7^{\circ} 10' 6''$ for the inclination of the equator, and $73^{\circ} 53' 6''$ for the longitude of the ascending node (*M.N.*, vol. lxxiii. p. 564).

The variation in the Sun's rotation period indicated by different spots in the same zones of latitude has been investigated by Professor Hirayama (*Journ. Coll. Sci. Imp. Univ. Tokyo*, vol. xxxii. No. 7). The observations seem to be best explained by supposing that there are two distinct rotation laws, one agreeing closely with that found by Maunder and others, while the second shows a general acceleration of about $0^{\circ} 35'$ per day. The angular velocity of "Drift I." is given by $\xi = 14^{\circ} 37' - 2^{\circ} 97' \sin^2 \lambda$, and that of "Drift II." by $\xi = 14^{\circ} 69' - 2^{\circ} 65' \sin^2 \lambda$, the mean ratio of the number of spots in each being 2 to 1. For the lower latitudes the velocity indicated by the second drift corresponds closely with the Edinburgh spectroscopic values, and it is suggested that certain

groups of spots may come to the level of the reversing layer and attain its angular velocity. It would be interesting to ascertain if the two drifts are associated with different types of spots.

Eclipses.—The eclipse of 1912 April 17 was observed under excellent conditions over a wide area, and the papers relating to it are very numerous (see *Nat.*, vols. lxxxix. and xc. ; *M.N.* ; *Comptes Rendus*, etc.). There was apparently a very brief totality in Portugal, and near the central line in the neighbourhood of Paris the eclipse was so nearly total that "Baily's beads" and some of the larger prominences were well displayed. Kinematograph records were obtained by some of the French observers. At Meudon M. Perot observed the green coronal line, but only on one side of the Sun : a hasty determination gave the wave-length as 5303·7, and it was noted that the line was much too broad for accurate determination of the rotation of the corona by the spectroscopic method. Mr. Worthington, who was stationed near Ovar, obtained a photograph of the flash spectrum, the chief value of which is to show the essential constancy of this spectrum. At Cambridge Professor Newall obtained some extremely interesting photographs of the spectrum of the reversing layer (*M.N.*, vol. lxxii. p. 536); and in visual observations at South Kensington, Mr. Fowler found that a nearly complete flash spectrum was visible at the cusps during thirty minutes (*M.N.*, vol. lxxii. p. 538). These observations indicate the possibility of usefully employing the most powerful spectrographs during future eclipses.

Numerous observers were stationed in Brazil for work during the total eclipse of 1912 October 10 ; but no results were obtained, in consequence of unfavourable weather.

Radium and the Chromosphere.—Considerable interest has been aroused by a discussion as to the possible presence of radium in the chromosphere. The supposed identification of this substance in Nova Geminorum led Dr. Dyson to make a similar comparison with the chromosphere, which has a close relation to the spectra of novæ at a certain stage, and it was concluded that five or six of the chromospheric lines might reasonably be attributed wholly or partially to radium (*Ast. Nach.*, 4589 ; *Obs.*, vol. xxxv. p. 297). The evidence was further examined by Dr. S. A. Mitchell (*Ast. Nach.*, 4600 ; *Obs.*, vol. xxxv. p. 357) and by Mr. Evershed (*Obs.*, vol. xxxv. p. 360), both concluding that there was no indication of radium among the chromospheric lines. Dr. Dyson does not consider the evidence to be very much weakened by these criticisms, and hopes that the question will receive attention at future eclipses. In view of the general prominence of rare metals in the chromosphere, and of the great brightness of the spark lines of so heavy a metal as barium, it is not unreasonable to suppose that radium spark lines might be present (*Obs.*, vol. xxxv. p. 402). The question is complicated by the chances of accidental coincidences in a spectrum containing so many lines as that of the chromosphere, and photographs with very high dispersion will be necessary to throw further light on the subject.

Pressure Displacements.—The pressure in the Sun's reversing layer, as determined from comparisons with the displacements of metallic lines under pressure, has been estimated at about 6 atmospheres. Messrs. Gale and Adams have accordingly made a careful and extensive study of these displacements, in the case of iron and titanium, under moderate pressures. Among the more general results, it appears that the displacements of enhanced lines are appreciably greater in an atmosphere of hydrogen than in air or carbon dioxide at the same pressure, although the other lines show the same displacements; also, that the displacements of the lines in the titanium spark are larger on the average than in the arc, the greatest differences being for the enhanced lines (*Ap. J.*, vol. xxxv. p. 10).

Pressure displacements of lines produced in the electric furnace have been investigated by A. S. King. The furnace has in general given displacements much larger than those found in spectra obtained from the electric arc (*Ap. J.*, vol. xxxv. p. 183).

It seems clear that deductions as to the pressures in the atmospheres of the Sun and stars must be made with great caution.

Theoretical papers relating to the cause of the pressure shift have been published by F. Sanford, W. J. Humphreys, and T. H. Havelock (*Ap. J.*, vol. xxxv. pp. 1, 268, 304).

Breadth of Spectrum Lines.—An important investigation of the breadth of spectrum lines in relation to the kinetic theory of gases has been made by MM. Buisson and Fabry (*Journ. de Phys.*, series 5, vol. ii. 442). All lines have a finite breadth, and in the case of a gas at low pressure, where collisions are negligible, the breadth is determined by Doppler displacements due to motion of the luminous particles. The velocities should then depend upon the temperature and atomic weight of the gas, and interferometer measurements of the breadths of lines are regarded as having completely verified the theory. This being established, the breadth of the lines will give an indication of the temperature of the source if the atomic weight of the gas be known, or *vice versa*. Experiments were made with vacuum tubes at ordinary room temperatures, and when immersed in liquid air; under the latter conditions, the lines were much reduced in breadth, and it is concluded that the temperature of the gas in a Geissler tube is the same as that of the surrounding medium. The luminosity of such a tube is therefore not of thermal origin. These researches may have an important bearing on several problems of celestial physics. For example, it has been found that enhanced lines, when produced electrically, give no indication of more elevated temperature than the arc lines, or of dissociation of the emitting particles into smaller masses; the condition for their emission seems to be an intense electric field, resulting in violent collisions between atoms and electrons. The production of such lines by thermal means would require extremely high temperatures, and their occurrence in certain

stars would therefore indicate very high temperatures if the emission be thermal in its origin. In another application, the measured breadths of the Fraunhofer lines have been found in excellent accordance with an absolute temperature of 6000° C. for the Sun's reversing layer, assuming the pressure to be about six atmospheres, as previously determined by the same authors from displacements of the lines towards the red. In the case of nebulae, the temperature may first be determined from lines known to be due to hydrogen, and the atomic weights of the gases giving the unknown lines may then be deduced; preliminary observations are unfavourable to the view that nebulae are at a very high temperature.

The Sun and Terrestrial Magnetism.—Father Cortie has discussed the relation of sun-spots to magnetic phenomena for the period 1898 to 1911. An explanation of the retardation of the maximum of magnetic activity on the spot maximum, and of the seasonal variation, is sought in the varying relation of the Earth's heliographic latitude to the sun-spot zones. The explanation appears to imply that magnetic disturbances are started by some influence which is propagated radially from sun-spot areas (*M.N.*, vol. lxxiii. p. 52).

Many numerical data are dealt with by Dr. Chree in a paper entitled "Some Phenomena of Sun-spots and of Terrestrial Magnetism at Kew Observatory" (*Phil. Trans.*, A, vol. cxxii. pp. 75-116).

Solar Radiation.—In a paper on "The Best Value of the Solar Constant," Messrs. Abbot and Fowle reply to the criticisms of their work made by F. W. Very last year. They maintain that their value of 1.92 calories per sq. cm. is entitled to confidence (*Ap. J.*, xxxv. p. 92). Mr. Abbot has made extensive observations in Algeria, with a view to testing the supposed variability of solar radiation, but the results have not yet been completely discussed (*Nat.*, vol. xc. p. 288). In a later official report, Mr. Abbot states: "It can now hardly be doubted that the outcome will prove conclusively the irregular short-period variability of the Sun."

From a comparison of the Washington values of the solar constant with the temperatures observed at Arequipa, H. Arctowski finds that a departure of 1° F. from the monthly mean corresponds to a variation of about 0.015 in the solar constant. A comparatively small reduction of the solar constant over a long period might thus account for such great climatic changes as occurred during the Pleistocene Ice Age (*Nat.*, vol. xc. p. 93).

The possibly important function of the ultra-violet radiation of the Sun in relation to terrestrial weather has been discussed by Dr. Ramsauer and C. Schultz (*Nat.*, vol. lxxxviii. p. 212, vol. lxxxix. p. 33, and vol. xc. p. 69).

A. F.

Double Stars.

The abbreviations used are—

M.N. : *Monthly Notices.*

A.N. : *Astronomische Nachrichten.*

L.O.B. : *Lick Observatory Bulletin.*

B.A.A. : *British Astronomical Association.*

A.S.P. : *Astronomical Society of the Pacific.*

New Doubles and Measures of known Pairs.—The new double stars discovered by M. Robert Jonckheere and his measures of known pairs are now published in the circulars issued from the Observatoire de Lille. Commencing 1912 April, and embracing all circulars up to and including No. 26, there are 204 new pairs (Nos. 708–921). Of the 921 pairs there are 556 under 3" separation.

The same circulars contain measures of known pairs, 180 stars in all, mostly Σ and Jonckheere pairs. M. Jonckheere observes with a 13 $\frac{3}{4}$ -inch refractor.

In No. 26 M. Jonckheere also gives measures of Sirius and Procyon:—

Sirius	1911'10	87°9	8"73	8 nights
Procyon	1911'06	23°7	4"70	2 "

Professor Aitken also gives measures of Sirius (*A.S.P.*, 144):—

Aitken	1912'08	83°6	9"58	2 nights
Barnard	1912'07	84°7	9"90	5 "

but neither of these observers has been able to measure Procyon.

In 1901 Professor Hussey began systematic measurement of Σ stars, with the intention of forming a volume on the lines of his *O Σ* volume (*Lick*, vol. v.). Already in 1902 some 2000 measures had been made with the 12- and 36-inch telescopes, when he had to devote his time to other work. The scheme was never completed, but the 2000 now published in *L.O.B.*, 206, form a very valuable contribution.

The June number *M.N.* contains measures by the Rev. T. E. R. Phillips with a 12 $\frac{1}{4}$ reflector and the 8-inch refractor lent by the Society. These measures, made in 1911 and 1912, are all of Σ pairs, 12 being under 2" separation and 38 over 2."

The usual annual results of measures made with the 28-inch Greenwich refractor, consisting of 685 pairs, are in *M.N.*, 1912 December.

Professor Burnham continues his measures of wide pairs with the 40-inch Yerkes refractor, and contributes a long series in *A.N.*, 4534.

Other measures for determination of proper motions consist of 58 pairs (Σ and H) made in 1911 and 1912, by Herren Luplau Janssen and Buch Andersen at the Urania Sternwarte, Copenhagen. A few pairs (14) are under 5" separation, *A.N.*, 4609.

Dr. Doberck has also devoted some time to the measurement of wide pairs. His contribution (*A.N.*, 4601) contains 28 pairs under 2" separation and 79 pairs over 2". The measures were made in 1910-11-12.

A useful set of measures of stars within 30° of N. Pole is published in *A.N.*, 4598. These were made by Ladislaus Benes, with the 6-inch refractor at Strassburg.

Annalen der Kaiserlichen Universitäts-Sternwarte in Strassburg, vol. ii., part ii., "Observations of Double Stars, with the 49 cm. Refractor, 1902-1910," Carl Witz. This publication contains 2152 measures of 867 stars from a working list of Σ , O Σ , and β pairs, with a few miscellaneous stars. Where the proper motion of the principal star was well known, the faint stars near were measured for determining their proper motion. The measures were made with the 19 $\frac{1}{4}$ -inch refractor of focal length 22 $\frac{3}{4}$ feet, the theoretical separating power of which is 0".26; but Herr Witz remarks that stars closer than 0".5 were not easily separated, and that a magnifying power exceeding 407 could not be used. The colours and magnitudes were also noted. Altogether this is a valuable piece of work.

There are two sets of measures of Southern stars. Mr. Tebbutt in *M.N.*, 1912 May, gives measures, made in 1911 with an 8-inch Cooke, of α Centauri, β 416, γ Centauri, γ Coronæ Aust., and β Muscæ. Mr. G. E. H. Beattie (New South Wales) gives measures, in *B.A.A.*, 1911 December, of 13 pairs, made with a 6.1-inch.

1911.8	α Centauri	215.6 and 19.20
1911.8	γ Cor. Aust.	105.0 " 2.01
1911.8	β Muscæ	350.2 " 0.99

In *L.O.B.*, 211, in a paper by Professor W. Campbell on "Radial Velocities of 212 Brighter Stars," will be found a number of doubles such as Sirius, Castor, O Σ 208, ζ Boötis, etc.; but a much larger number will be found in *L.O.B.*, 214, in a further paper entitled "On the Real Motions of 100 Stars."

Computational and Theoretical Papers.—In a paper entitled "Über die Vorteile der Anwendung eines Reversionsprismas bei Doppelsternmessungen," and communicated to the Prussian Royal Academy of Sciences, Professor H. Struve gives results of some experimental measures made with and without a reversion prism. The measures were made by himself and Dr. Guthnick. The results show that the mean of the two methods practically eliminates systematic error, which is small in the case of Dr. Guthnick, but larger in his own case. He recommends the use of the reversion prism. As an example: the probable error of an observation of Σ 2603, separation 3".2.

Σ Single Observation.	Combined.	Guthnick Single Observation.	Combined.
$\pm 2^{\circ}.62$	$\pm 1^{\circ}.02$	$\pm 1^{\circ}.11$	$\pm 0^{\circ}.83$

A paper by K. Schiller on the same subject is in *A.N.*, 4585. The observations in this instance were made with the 29-cm. refractor at Bothkamp. Herr Schiller arrives at the conclusion that the mean of the two methods is somewhat better than the single observation by either method, but not so markedly as Struve finds. The paper contains further suggestions for eliminating systematic error due to the position of the head, *e.g.* by the use of two prisms; and also some hints as to fitting the prisms.

In *A.S.P.*, 142, Professor Aitken deduces orbits for β 101 (23.3 years), β 581 (46.5), O Σ 79 (88.9), and O Σ 235 (71.9) which are very similar to those previously computed. In *Popular Astronomy*, 1912 December, he has an interesting note on the systems O Σ 568 and O Σ 341. These are binaries with an orbital motion lying in the plane of the line of sight. But of more importance is a paper by him in *A.S.P.*, 144. In this Professor Aitken has succeeded in deducing an orbit for ϵ Hydræ A B (Schiaparelli) which satisfies both visual and spectroscopic observations. He uses a period of 5588 days.

"On Changes of Photographic Films found by Measurements of Double Stars," *A.N.*, 4588. M. Lau measured, in 1911.1, the distances between the images of 45 double stars taken with the Merz refractor of the Urania Observatory—aperture, 16 cm., focal length, 3.3 m. Measures of the same images were repeated in 1912.1 with a view to the detection of any possible alteration in the film during the interval. The pairs were arranged in order of separation (2".8–16".4). For the stars less than 8" separation he could not fairly be said to show any change, but for those over 8" he found an apparent increase of distance +0".06.

In the *Astrophysical Journal*, vol. xxxi. p. 185, Dr. H. N. Russell, from a discussion of stability in nebulous masses, finds that the theory that the original mass was split up into two or more fits in with the observed facts, in the case of the closer systems, better than the theory of segregation nuclei in the parent nebula. For the wider systems and for clusters the development of the separate nuclei offers the more probable explanation.

Mr. E. H. Beattie, in *B.A.A.*, 1912 October, has a note on the motion and variability of the southern binary Lacaille 7194.

In No. 36 of the circulars issued from the Observatory of the University of Lille, M. Robert Jonckheere, from elements in Dr. See's *Evolution of Stellar Systems*, 1895, gives computed places for Σ 3062, Sirius, β 101, ζ Cancri, and Σ 1356 up to the year 1920.

T. L.

Variable Stars.

The study of variable stars, and researches in relation to the phenomena they present, have been pursued with increasing energy in the past year. Numerous additions have been made to the already considerable list of stars which vary in their apparent

brightness, and the result of the extensive discoveries made in recent years is to create so large a mass of material for further research as must seriously tax the energy of astronomers. The various astronomical publications show that already a large number of observers are devoting themselves to this important department. It is quite clear that the subject of variable stars must be broken up into two broad classes—the first consisting of variable stars proper, viz., stars which from their constitution have periodic variations in their intrinsic brightness; and secondly, of eclipsing binaries: stars whose brightness is affected by partial occultation by a dark or less luminous star. In addition to these are the new stars which suddenly burst into luminosity.

The extraordinary value of the extensive and continuous series of photographs secured by the organisation of Harvard College Observatory has been repeatedly demonstrated by the discovery of many variable stars, by the data afforded for the estimation of approximate periods, and also in confirming or disproving the discovery of novæ.

Among the more important publications of the past year is the completion of vol. xlvii. of the *Annals of Harvard College* on "Photographic Observations of Variable Stars during the years 1886-1905." The first part of this volume, published a few years back, was devoted to a discussion and determination of the provisional photographic magnitudes of the comparison stars. On this subject Professor Pickering states that "no satisfactory method has yet been devised for determining the absolute photographic magnitudes of the stars. This is especially the case with the fainter stars, and the errors and uncertainties of this portion of the scale may still be large—on the other hand, the relative brightness of different stars, even if faint, can be determined with great accuracy by the method of Argelander. If, then, the magnitudes can be obtained upon a scale consistent with itself, they can be reduced without difficulty to an absolute scale when hereafter such a scale can be determined." The second part of this volume, just published, is devoted to the determination of the photographic magnitudes of 107 variable stars of long period in relation to the comparison stars previously published. The whole of the work was accomplished by the late Mrs. Fleming, Miss Breslin, and Miss Gill.

Vol. lxiii. of the Harvard College *Annals*, recently distributed, is devoted to the observations of 328 variables made in the period 1906 to 1910 mainly by Mr. Campbell.

The publication in the past year of the seventh report of the Variable Star Section of the British Astronomical Association forms a very valuable contribution to the subject. This volume contains the visual observations of 21 long-period variables made in the years 1905 to 1909, embracing some 14,000 observations, collated and prepared for publication by Colonel E. E. Markwick. In a note by Professor Turner appended to this work he remarks that "several variables have been watched continuously throughout

the whole of their light-curves by a number of observers, and for the first time it is possible to obtain direct evidence on several points on which we had previously only suspicions." Professor Turner has elsewhere laid great stress on continuity of observations, and this volume testifies what good work can be done by such an organisation as the Variable Star Section.

Eclipsing Binaries.—The great importance of the application of photometric methods to variable stars is exemplified by the researches recently made on eclipsing binary stars. Professor Shapley remarks that "the distinctions formerly made between variable stars of the type of Algol, and of the type of Beta Lyræ, have so completely vanished with the increased refinement of the photometric work of recent years, that it is no longer possible to use consistently the old classification." No more valuable research on such variable stars has appeared than the series of papers by Professor H. N. Russell in vols. xxxv. and xxxvi. of the *Astrophysical Journal*, "On the Determination of the Orbital Elements of Eclipsing Variable Stars." In his first paper he discusses under what circumstances and to what degree this problem, in view of the limited accuracy of photometric observations, may be regarded as determinate. After a full discussion he arrives at the conclusion: "To the degree of approximation attained by any existing photometric measures, the problem of determining the elements of an eclipsing variable, solely from the light-curve of a primary minimum, without constant phase, is indeterminate." Further investigation indicates the possibility of determining from the light-curve of an eclipsing variable with constant phase, the radii of the two stars in terms of the distance separating them; the inclination of the orbit to the line of sight; the light of each star, and their relative surface brightness; the mean density of the system in terms of the Sun's density; the elongation of the stars towards each other due to their mutual attraction; the radiation effect of one star upon the other; the eccentricity of the orbit; and the longitude of periastron. But, as Professor Shapley points out, in only very few cases are the data sufficiently accurate to determine all these quantities.

Professor Russell gives the result of the application of his methods to determine the elements of the eclipsing variables W Delphini, W Ursæ Majoris, and W Crucis. As an example we may give the elements he obtains for W Delphini, an Algol variable with a deep primary minimum showing a constant phase and little or no secondary minimum.

Taking the radius of the orbit as unity

Radius of the larger star	. . .	0.256
Radius of the smaller star	. . .	0.135
Inclination of orbit plane	. . .	82° 25'
Least apparent distance of centres	. . .	0.114
Light of larger star	. . .	0.0832
Light of smaller star	. . .	0.09168

At the middle of eclipse the larger star overlaps the other by only 0.007 of the radius of the orbit, or about $\frac{1}{150}$ of the radius of the smaller body, so that the eclipse is very nearly grazing. The smaller star gives off eleven times as much light as the other, and exceeds it fortyfold in surface brightness.

Further interesting contributions to the subject by Professor Russell and Professor Shapley are found in vol. xxxvi.: "On Darkening at the Limb in Eclipsing Variables," in which is given a most useful summary of the theory of eclipsing variables, with the notation employed, functional notation, and fundamental equations for spherical stars—supplemented by "Directions for the Computer," which cannot but prove of the greatest utility.

In the same volume Professor Shapley has made a further contribution to this important subject, in which he discusses the elements of the eclipsing variables W Delphini, S Cancri, SW Cygni, and U Cephei. He has also published a most interesting paper on the general question of eclipsing binaries, reprinted in *Popular Astronomy* for November 1912.

An exhaustive discussion of the Algol system Z Draconis, by Professor R. S. Dugan, forms No. 2 of the contributions from the Princeton University Observatory. He states that the entire phenomenon of primary minimum in this remarkable star takes place in about six hours, in which the brightness drops 2.55 magnitudes. There appears also to be a small secondary minimum. The study of the light-curve leads him to conclude that it is a binary system whose components are elongated in their line of centres; are brighter on the sides which face each other than on the opposite sides; present disks darkened towards the limb; and partially eclipse each other in their revolution. Professor Dugan appends the elements of the system which he has computed by the methods of Professor Russell.

The above papers form a striking example of the refinement that is attainable by modern astronomical methods.

The publications of the Astrophysical Observatory at Potsdam contain an important discussion by Professor Kronn of all available observations of XX Cygni (the shortest period variable known) since its discovery in 1904. Eight series of visual, and one of photographic observations, extending over seven years, were used. Small but important corrections are obtained to the epoch of maximum, and to the period (which is 3.2 hours approximately), and evidence is found for a small secular change of period. It is pointed out that, so far as present knowledge goes, the hypothesis that this secular change is due to the revolution of XX Cygni and its companion round a third body (as in the case of δ Cephei and the Pole Star) leads to no extravagant dimensions for the system. The light-curve is concluded to be of the δ Cephei type, and not of the cluster variable type. A small oscillation of light intensity producing a tendency to a second maximum is also found; the interval of time between the primary and secondary maxima undergoes a harmonic oscillation in the course of about three years. The

author finds some evidence of a similar phenomenon in the case of η Aquilæ.

Nova Geminorum.—On the evening of 1912 March 12, at 8^h 32^m Mid-European time, Mr Sigurd Enebo, at Dombaas in Norway, discovered with the naked eye a new bright star in a rather blank part of the heavens near θ Geminorum. He at once communicated with the Kiel Centralstelle, who immediately telegraphed the discovery to the principal observatories of the world, which enabled them to observe the star on the following night. At the time of Mr. Enebo's discovery the brightness of the star was about 4.2 mag.

In Harvard College Circular 176 Professor Pickering states that an examination of the photographs of that observatory showed no sign of the nova on Sunday March 10 at 13^h 22^m G.M.T., although stars as faint as the eleventh magnitude appear; but a photograph taken the following night, March 11 at 12^h 13^m G.M.T., shows the nova as a star of the photographic magnitude 4.5. It follows that the star appeared in the course of the previous 23 hours. An examination of earlier Harvard photographs showed a star of mag. 14 near, but apparently not identical with, the nova. The Astronomer Royal has also found, on comparing Greenwich photographs with one of Franklin-Adams chart plates, that the nova may be coincident with one of two small stars of the fifteenth or sixteenth magnitude. The promptness with which the discovery was communicated to the world enabled a large number of observations to be secured, not only of the gradations in the star's brightness, but also of its spectra, which are referred to elsewhere.

When discovered on March 12 the magnitude was 4.2. It got rapidly brighter, and reached its greatest brilliancy on March 14. Photometric measurements at Harvard give the following times and magnitudes under this date:—

Julian Day.	Magnitude.
2,419 476.526	3.77
.533	3.47
.540	3.37

It was observed also on this date by Ristenpart as 3.5 mag., and by Padova at Catania as 3.77 mag. The star then rapidly decreased in brightness, and on March 16 was 5.3 mag. Several series of observations of brightness have been published: by Padova, from March 13 to May 19 (*Ast. Nach.*, 4598); Ebell, at Kiel, from March 13 to April 2 (*Ast. Nach.*, 4564); Ristenpart, March 14 to April 21 (*Ast. Nach.*, 4624); Rambaut, March 13 to April 10 (*M.N.*, April); Greenwich series of photographic magnitudes, March 15 to April 16; Berlin Observatory, March 12 to May 21 (*Ast. Nach.*, 4624); Petersen, a full discussion of all observations with light-curve, from March 12 to May 30 (*Ast. Nach.*, 4608); Lazzarino (*Ast. Nach.*, 4624); Potsdam (*Ast. Nach.*, 4624); Leonard, March 15 to May 13 (*Pop. Ast.*, May);

Harvard, a careful series of photometric measures from March 14 to June 5 (*H.C.*, 175).

Numerous fluctuations in the light took place, as in the case of Nova Persei; but by no means to the same extent. In the absence of a light-curve diagram it may be sufficient to consider the salient points of the curve as maxima, and the depressions as minima, as follows:—

	Mag.		Mag.
<i>Maxima.</i> —March 14	3'4	<i>Minima.</i> —March 16	5'3
„ 17	5'2	„ 20	5'6
„ 24	4'6	„ 27	6'2
„ 30	5'5	April 4	6'3
April 5	5'9	„ 6	6'6
„ 10	6'3	„ 13	6'5
„ 19	6'4	„ 26	7'2

The notable features of the curve are the increase in brightness between March 20 and 24, and the sudden drop of 1'6 mag. between March 24 and 27. At the early part of June the magnitude was 7'5, which diminished to 7'7 at the end of August, and at the end of September the nova was reported to be at 8'2 mag.

Some observations of colour were made by Dr. Rambaut, Mr. Leonard, and others. Dr. Rambaut found the nova on March 20 to be orange with no red colour. March 25 it had become redder, and thereafter the colour was stated to be orange with a red fringe. Mr. Leonard found it on March 15 very pale yellow; on the 19th it changed to a pinkish colour. On the increase in brightness on March 24 it appeared creamy white; from that date the colour became more red, until on April 11 it appeared deep red.

The position of the nova has been determined at several observatories from meridian observations and from measurements of photographs. A careful discussion of the question by Mr. Bellamy appeared in the *Monthly Notices* for April, in which, from measurements of a photograph taken at Oxford, he finds the position for 1912'0 as R.A. 6^h 49^m 11^s·83, Decl. +32° 15' 6"·7. E. B. K.

Stellar Distribution and Drift.

Stellar Parallaxes.—The valuable series of determinations of stellar parallax with the Yale heliometer has been further extended by a new instalment, which completes vol. ii. of the *Transactions of the Astronomical Observatory of Yale University*. This contains 41 stars in the zone between the Equator and Dec. −13°. Most of these were selected on account of their large proper motion, exceeding half a second per annum; the remainder were second magnitude stars. The observers, F. L. Chase and M. F.

Smith, carried through this heavy programme in two years. The results reveal several new parallaxes of considerable amount; the greatest are

ϵ Eridani	$0\cdot31 \pm 0\cdot014$
δ Eridani	$0\cdot18 \pm 0\cdot015$
Weisse 16 ^h , 906	$0\cdot21 \pm 0\cdot016$

The last-named is an 8^m.8 star, with an annual proper motion of $1''\cdot29$.

The nearness of ϵ Eridani had been suspected before, but could not be considered satisfactorily established. According to the Yale determination, it must be one of the dozen nearest neighbours of the Sun.

The whole series of Yale parallaxes now includes a total of 238 stars. A complete catalogue of these, and a comparison with the results of other observers, where such exist, are given at the end of the volume. The statistical tables giving the average parallaxes of stars of different brightness and proper motion are of much interest; but it is clear that a great deal more work will need to be done before any definite formulæ can be derived by this direct mode of attack.

A second series of stellar parallax determinations from meridian transits at the Washburn Observatory is published by A. S. Flint in *Astron. Journ.*, No. 631. The list includes 124 stars mainly of the second or third magnitude; the general probable error given is about $\pm 0\cdot03$. There is probably some difference of opinion among astronomers as to the reliability of parallax determinations made by transit observations. The present list provides a good means of testing the results by comparison with other methods; it would be useful if such a comparison were made. We find it difficult to accept the parallax $0\cdot16$ given for β Canis Majoris, an Orion type star with imperceptible proper motion; that of Algol, $0\cdot13$, type B8, also seems improbable. On the other hand, ϵ Eridani (referred to above) gives the large value of $0\cdot38$ in fair accordance with Chase and Smith's result.

Additional stars with annual motions exceeding $1''$ are rarely discovered now; attention may therefore be called to the star B.D. + 42° 2810, mag. 9.4, which was found by S. Kostinsky to have a motion of $1''\cdot11$ per annum (*Ast. Nach.*, 4569). It is worth the attention of parallax-hunters.

Radial Velocities.—A considerable number of the radial velocities of stars, determined at or under the direction of the Lick Observatory, have been published during the year. *L.O.B.*, No. 211, contains the results for 212 stars of type A; it will be remembered that the type B stars (225 in number) were given in *L.O.B.*, No. 195, published in 1911. The radial velocities of 100 stars, chiefly of more advanced types, are published incidentally in *L.O.B.*, No. 214. Further, there are the radial velocities of 150 stars south of Dec. -20° determined by the D. O. Mills

Expedition, 1903-6 (*Publications of the Lick Observatory*, vol. ix. pt. iv.). This list partly overlaps the others mentioned.

W. W. Campbell's discussion of the radial velocities of the type A stars contains some results of great interest. A table is given which is intended to assist in disentangling the preferential motions towards Kapteyn's vertices from a possible general tendency of the stars to move parallel to the plane of the Milky Way. After correcting for a solar motion of 19.5 km. per sec. towards the solar apex R.A. 270° , Dec. $+30^\circ$, the average residual velocities (irrespective of sign) show the following results:—

Galactic Latitude.	Average Residual Velocities. Type A.		
	Distance from Kapteyn's Vertices.		
	$0^\circ - 30^\circ$.	$30^\circ - 60^\circ$.	$60^\circ - 90^\circ$.
$0^\circ - 30^\circ$	15.9 ₃₃	10.3 ₃₃	11.7 ₃₅ km./sec.
$30^\circ - 60^\circ$	...	11.2 ₄₆	7.6 ₃₆
$60^\circ - 90^\circ$	...	...	9.3 ₂₉

The suffixes show the number of stars.

The preferential motions are indicated in the decrease of the numbers from left to right of the table. A general tendency to move parallel to the plane of the Milky Way would be shown by a decrease of the numbers from top to bottom of the columns; this does not seem to be indicated. The figures are somewhat irregular, and evidently more data are required; but taking the numbers as they stand, there would appear to be no tendency of the stars to move parallel to the Milky Way, apart from that involved in the two star-stream motions. Campbell's new table is in this respect opposed to his former results.

The difficulty of obtaining in sufficient quantity direct data as to the distances and linear motions of individual stars has suggested tentative determinations of these quantities on more or less approximate hypotheses. The results are not intended to be regarded as reliable, but may be suggestive of lines of future inquiry. H. C. Plummer (*M.N.*, vol. lxxii. pp. 170, 555) has evaluated parallaxes and absolute motions of the stars of types A and B on the supposition that they are moving parallel to the galactic plane. He has traced associations of these stars into groups according to the resulting motions. H. C. Wilson (*L.O.B.*, No. 214) has discussed the directions of the real motions of the stars of large proper motion for different assumed values of their distances.

The Star-Streams.—H. H. Turner (*M.N.*, vol. lxxii. pp. 387, 474) has suggested an explanation of the phenomena of two star-streams, as arising from the nature of the orbits of the stars under the central attraction of the sidereal system. He supposes that the stars for the most part move in very elongated orbits about the centre, so that they may be compared to the comets of the solar system. In such a case the motions to and from the centre would preponderate over the transverse motions, and the radial directions

would (in any part of space) be preferential directions of motion. He discusses which of the two vertices corresponds to the centre of the system, and decides in favour of the vertex at R.A. 94° , Dec. $+12^{\circ}$. The knowledge that the velocities of the stars in the earliest stage of development are extremely small, accords well with this view that stellar motions are mainly radial, *i.e.* produced by the central attraction of the universe. The great difficulty, however, is to construct a dynamical model in which the motions would be preponderatingly radial, without having an extreme congestion of stars in the neighbourhood of the centre. If the system is considered to be in anything approaching a steady state, the necessary increase of density towards the centre is very rapid.

J. C. Kapteyn's original investigation of 1904, in which he determined for the first time the elements of the two star-streams, is at length published in full (*M.N.*, lxxii. p. 743). His method differs considerably from those of later investigators. On the question whether there is a real division of the stars into two drifts, or whether the ellipsoidal hypothesis of Schwarzschild represents the motions more accurately, he points out that his formulæ can represent a distribution with or without appreciable division into two systems according to the value of a certain parameter; the value actually determined by him corresponds to a clear division into two systems. It seems doubtful, however, whether any stress should be laid on this evidence: the parameter in question is mainly a quantitative measure of the polarity of the motions; and it is merely a consequence of the mathematical expression adopted, that, since this polarity exceeds a certain amount, the motions appear to proceed from two separate systems.

By a different method an attempt to decide between the ellipsoidal and two-drift hypotheses is made by A. S. Eddington (*M.N.*, lxxii. p. 368). The law of distribution of the linear motions of the stars can be derived from the laws of distribution of the angular motions and of the distribution of the stars as regards distance, by the solution of an integral equation. The difficulty lies mainly in our imperfect knowledge of the law of distance of the stars; it was found, for instance, that Kapteyn's determination of this could not be reconciled with the proper motions of Boss's catalogue. The result of the discussion indicates a definite separation into two distinct drifts. But the evidence is not entirely reliable. At present the main difficulty in the use of the ellipsoidal representation is that, containing one less disposable constant than the two-drift formulæ, it cannot be fitted to the recent and more refined proper motion data sufficiently closely.

A study of the systematic motions of the stars, divided according to spectral type, has been made by Benjamin Boss (*Astron. Jour.*, Nos. 635-6). The principal difficulty is that, with the necessity of treating limited areas of the sky, and with this additional subdivision according to type, the data tend to become very scanty. Boss minimises this by combining together

a considerable number of areas of the sky, making the directions towards the vertex coincide; but to do this he has to apply a correction (necessarily imperfect) for the solar motion. The effects of the preferential motions are shown very strikingly in the diagrams; and the stronger polarity of the motions of the type A stars as compared with the later types is well exhibited. The conclusions of the paper, which deal with the stage of the stars' development at which the preferential motions are acquired, and the relation of the effect to galactic latitude, are too complicated to be described here.

General.—A most valuable paper on the formulæ of stellar statistics is given by K. Schwarzschild (*Ast. Nach.*, 4557). In the most concise form the formulæ connecting all the principal statistical data with the fundamental distribution-functions of star-density, light-power, and velocity, are derived. The formulæ are worked out fully in special cases of practical importance. C. V. L. Charlier ("*Meddelanden*" of the *Astronomical Observatory of Lund*, series ii. no. 8) has studied the distribution and luminosity laws of the stars with special reference to the nature of the Milky Way. His numerical results are based on the counts of the Bonn Durchmusterung and of the Carte du Ciel; they are regarded as provisional only. The memoir is the first of a series of three in preparation.

It is well known that certain classes of celestial objects show a marked tendency to congregate towards the galactic plane. E. Hertzsprung (*Ast. Nach.*, 4600) enumerates seven classes of such bodies, and calculates the exact positions of their planes of greatest concentration. The agreement of the planes which are thus defined is very striking:—

Class.	Pole of the Plane of Concentration.		No. of Objects.
	R.A.	Dec.	
Helium stars (Oe5-B9)	182°1	+ 27°9	1402
Eclipsing variables	188°2	25°8	150
c and ac stars (A. C. Maury)	189°1	26°3	98
Stars of Type V. (Oa-Oe)	190°7	26°9	87
Gaseous nebulae	192°7	28°1	130
Stars of Type IV.	194°2	27°4	228
Cepheid variables	195°9	26°8	60
Galactic pole (Pickering)	190	28	...

An observational result found by E. A. Fath (*Ap. J.*, xxxvi. p. 362), that the integrated spectrum of the Milky Way is approximately of the solar type, seems at first sight very surprising. The well-known phenomenon, that stars of the Orion and Sirian types are strongly concentrated towards the Milky Way, has led to the general opinion that the faint stars in this region are mainly of these early types. Nevertheless, a little consideration

shows that Fath's result might perhaps have been anticipated. If the different types are mixed in the same proportions in all parts of space (and there is at present no reason to suppose otherwise), we may divide space up into a number of volumes each of which will give an integrated spectrum of precisely the same character; the observational result then means that the total light of all the stars in any restricted volume of space is predominantly of a solar type. On the other hand, when, instead of considering the stars in a volume of space, we consider those brighter than a limiting magnitude, the luminous early type stars are drawn from a much larger volume of space than the fainter solar type, and are therefore included in disproportionately large numbers. This accounts for the apparent excess of early type stars usually found. The knowledge, that the resultant light of our stellar system is of the solar type, favours the analogy which has been drawn between it and such a system as the Andromeda nebula, which yields a similar spectrum.

A. S. E.

Photographic Magnitudes.

The prospects for the determination of the photographic magnitudes of stars in large numbers, down to a considerable degree of faintness, have improved very greatly during the past year or two. The question has received special attention at Harvard, where Professor E. C. Pickering's long-continued work has resulted in the determination of the photographic magnitudes of a number of stars near the North Pole, on an absolute scale, ranging from the first to the twenty-first magnitude. This group of 96 stars forms a valuable standard sequence with which the stars in other regions may be compared, its stationary position in the sky being favourable for this purpose. Among other observatories which have been working on photographic magnitudes may be mentioned Göttingen, Yerkes, Mount Wilson, and Greenwich. Owing to the improvement in photographic methods, it is now possible to determine the photographic magnitude of a star (at any rate down to 9^m or 10^m) from a single plate, with a probable error of less than $0^m \cdot 1$.

An absolute scale of photographic magnitude is defined by its zero point and its light ratio (the ratio of light intensity corresponding to an interval of one magnitude). Owing to atmospheric changes, the light standard defining the zero must be stellar, and not terrestrial. The zero point is of little intrinsic importance, but it is desirable that the same one should be used by all observatories, or that the differences between the zero of the various magnitude scales in use should be known. The light ratio corresponding to an interval of one magnitude should be constant at all parts of the scale (its amount has been fixed by convention at 2.512). This is the prime condition which must be fulfilled

by any absolute scale which is defined by the determined magnitudes of a given group of stars, like the Harvard polar sequence.

To ensure conformity between the work of different observatories, the Committee on Star-magnitudes of the last Astrographic Conference recommended that the zero of the magnitude scale should be defined in such a way that the Ao type stars of the Harvard classification, and of magnitude 5.5 to 6.5, should have the same photographic and visual magnitudes in the mean, the visual magnitude being reckoned on the Harvard scale. This "international" scale zero has been adopted at Göttingen and Yerkes.

The measurements made in the determination of photographic magnitudes may be of diameters of star images, or of their greyness-intensity (in which case the images are generally made extra-focal), or of a combination of both (by a comparison with a graduated sequence of comparison images). It is then necessary to know the relation between the magnitude m , and the measured quantity d (diameter), i (intensity), or x (number on comparison sequence); the relation may be expressed as a table, curve, or formula, as, *e.g.*, the diameter formula $m = C - k \sqrt{d}$, which has been found to hold good over a range of three or four magnitudes, the constants C and k depending on the conditions of the particular photographic plate. The same relation may not be exactly true all over a plate, so that corrections may have to be applied to allow for the effect of distance from the plate centre, or of differential atmospheric absorption (if the plate covers a considerable range of declination).

If the relation between m , and d , i , or x (whichever be the measured quantity) be known or assumed for a given plate or group of stars, the magnitude scale thus defined may be used in all parts of the sky in either of two ways: viz., by equal successive exposures on the standard region and the comparison region, under conditions as nearly identical as possible, or by a series of overlapping plates extending from one region to the other. In both cases the assumed magnitudes of the stars of the standard region are used to determine, either by a single step or by a succession of steps, the magnitude curve for the plate containing the stars whose magnitudes are desired; these magnitudes are then deducible from the known magnitude relation.

The method of duplicate exposures gives the best guarantee against accumulation of systematic error, but great care is necessary to ensure identity of conditions for the two exposures. The focus of the instrument must not change, and the sensitivity of the plate must remain constant throughout the exposure period; at Harvard some difficulty has been found in keeping the plate uniformly sensitive, apparently owing to the deposit of a fine film of dew on the plate, which diminishes the sensitiveness: this trouble has been overcome at Greenwich by keeping the plate slightly warm, an electric current being circulated through a network of resistance wires stretched behind a metal plate which forms the back of the dark slide. The most serious difficulty,

however, is in ensuring equality of the atmospheric conditions; the two regions must be photographed when at the same altitude, of course, but it is not easy to be certain that changes in atmospheric transparency are not taking place. Only nights with a really uniform sky and without a bright moon can be used, and it is desirable to make a third exposure, on the region first photographed, in order to have a check on the uniformity of the sky. Another method is to point a stationary "patrol" camera towards the pole, so that the star trails may reveal any serious change in the transparency of the air. In spite of these precautions, however, any method of photographic photometry which depends on the use of two equal exposures on one plate is unsuitable for faint stars which require exposures of thirty minutes and more (at any rate, unless the climate is exceptionally good); this is so not only on the score of accuracy, but also on account of the waste of time upon unfinished plates.

The method of overlapping plates, with one exposure on each, is free from this last drawback, and is in many ways a very simple and good method of applying a magnitude scale to a continuous region of the sky. The magnitude relation for each plate is determined from the known magnitudes of the stars in the part of the plate (generally one-half) covered also by the preceding plate. It is necessary to examine the systematic errors which are sure to arise in this "carrying on" process, but this does not offer any great difficulty. A method of this kind was used by Schwarzschild in his "Aktinometrie" (*Abh. d. k. Gesell. d. Wiss. zu Göttingen*, vi. 6 (1910), and viii. 4 (1912)), and to a less extent by Parkhurst ("Actinometry," *Ap. J.*, xxxix. 169, 1912).

If the magnitude scale adopted on the first plate is an absolute one, the magnitudes of the stars on remaining plates (when freed from errors of comparison) are also on an absolute scale with a fixed zero over the whole region; if not, they can be made absolute by determining the errors of the scale on the first region. It will next be considered, therefore, how an absolute scale of magnitudes can be formed for any one region. It may be noticed, however, that if the photometric method employed enables this to be done on each region photographed (as in Parkhurst's work), the use of overlapping plates is still necessary to keep the scale-zero constant from plate to plate.

The methods of measuring absolute magnitude intervals on a single plate are very numerous. One of the earliest methods tried was that of giving two exposures of different lengths on the same plate, and assuming that the two sets of images differed by $0.4 \log t_1/t_2$ magnitudes. This is unsound, and leads to erroneous results, because the star image does not depend only on Jt (where J = the intensity of the light and t is the total exposure time). Abney (*Proc. Roy. Soc.*, 1893) has shown that the proportion of light energy which is transformed in the photographic film to chemical energy depends on the conditions under which the light energy is received: for any particular film there is a particular light intensity

for which the proportion of energy transformed is a maximum. The intensities usual in stellar photography are much below this value, and therefore an increase of intensity increases the proportion of energy transformed—in other words, an intenser light for a shorter time is more effective than a weaker light for a longer time, if Jt is the same in the two cases. Abney also showed in the same paper that an intermittent exposure was less effective than a continuous exposure. Schwarzschild (*Publ. d. v. Kuffnerschen Sternwarte*, 5, 1897) finds that Jt^p , where p is an index less than unity, is the quantity which determines the size and character of a star image; he gave 0.70 as the value of p for extra focal images on the plates used in his investigation. The constant p varies with the plates used, and especially with the quality of the light when colour filters are applied; thus Parkhurst (also using extra focal images) (*Ap. J.*, 30, 33, 1909) found values of p more nearly equal to 0.8 than 0.7. Charlier (*A. G. Publ.*, 19, 1889), using focal images, found $p=0.68$ (this result is probably too small, as the intensity scale was not well determined). Schwarzschild in his *Aktinometrie* (1912) gives $p=0.76$, stating that this “rather low” value may be due to the intermittency of the light with his method.

The principal methods which have been applied with success are as follows:

(a) Successive exposures with and without an opaque screen partly covering the objective, (b) successive exposures with and without an absorbing screen or grating, (c) successive exposures with the plate at different distances from focus, (d) a single exposure with two pieces of Iceland spar placed in front of the plate, (e) a single exposure with an auxiliary prism of very small angle placed before the objective, (f) a single exposure with a parallel grating in front of the objective, and (g) a single sky-exposure, using extra-focal images, with a second exposure in a sensitometer box in order to impress a magnitude scale on each plate.

Methods depending on the use of opaque screens have been used at Harvard and Mount Wilson, and seem to allow of a wide range of reduction in the light forming a star image without the calculated drop of magnitude being affected by diffraction phenomena or inequalities in the objective: a drop of 5 magnitudes has thus been obtained at Mount Wilson.

In connection with method (b), depending on the use of an absorbing diaphragm, it may be noted that wire gauze or cloth “gratings” are preferable to neutral glass screens, as they do not affect the spectral type of the light at all. The diffraction images obtained with gratings are neglected, and the absorption constant of the grating is determined by means of a photometer. The absorbing screen may be placed either at the objective end of the telescope or a few cm. in front of the photographic plate. In the latter case the grating is often made so as only to half-cover the plate; this (Halbgitter) method was developed by Schwarzschild (*A.N.*, 183, 297-308) from a suggestion by Kapteyn. The two

exposures, with and without the grating, need not be of the same length; suppose x is the measured quantity (intensity or diameter) relating to the first image of a star of magnitude m (without the grating) and x' or x'' that corresponding to the second image, according as it falls outside the half of the plate covered by the grating, or not. If we write $x=f(m)$, we shall have $x'=f(m+a)$, where a is an unknown depending on the difference between the exposures, and $x''=f(m+a+\delta)$, where δ is the known absorption constant of the grating. From a number of corresponding values of x and x' , and x and x'' , the slope of the curve $x=f(m)$, for different values of x , can be readily obtained.

The method (c), depending on extra-focal images at different distances, has been used at Harvard to determine the magnitude difference between the Pole star and other stars, the image being made nearly equal by altering the focus for the two stars. The distance from the focus can be measured or checked by the size of the image, which is made rectangular by placing a rectangular screen over the objective.

The principle of the methods (d), (e), and (f) is the same, viz., to divide up the light from a star into definite proportions (representing definite magnitude differences), each of which goes to form a separate image. All the images are subject to exactly the same conditions of exposure and development. The division of the light may be effected either by a small prism in front of the objective, by plates of Iceland spar turned at a particular angle, or by a diffraction grating of parallel wires or strips. In each case, by suitable choice of dimensions, the secondary images can be made sensibly round, like an ordinary star image; this condition, of course, is essential. The relative advantages of the three methods therefore depend on their convenience and on the accuracy with which the proportion of light deflected can be measured. The latter depends in case (d) on the ratio of the area of the prism to that of the whole objective, in (e) on the angle at which the Iceland spar plates are turned, and in (f) on the ratio of the width of the strips or wires to their distance apart. Such methods as these seem to be the most promising ones at present; the grating method, in particular, seems well adapted to give an accurate determination of absolute magnitude-intervals.

The last method (g) has been applied with success by Parkhurst. The relation between light-intensity and the greyness of the extra-focal images was determined on each plate, by placing this in a "sensitometer" box (*Ap. J.*, **26**, 244, 1907; **36**, 169, 1912) and photographing on it a number of small discs, produced by light sources whose intensity-ratios were absolutely known. This is done after the sky-exposure and before development, and enabled the magnitude scale to be easily and accurately determined on each plate, by measurement of greyness in a microphotometer.

As regards the zero of the magnitude scale (a question which seriously arises in every scheme of photometry not based on a standard sequence of comparison stars, by the method of direct

comparison, with duplicate exposures), this must first be made uniform over the whole region dealt with, by means of overlapping plates; then, if the magnitude range includes the interval $5^m.5$ to $6^m.5$ on the Harvard visual scale, the magnitude scale may be brought into accordance with the international Astrographic scale by applying such a constant correction to all the magnitudes as will make the 40 stars of magnitude 5.5 to 6.5 to have the same photographic and (Harvard) visual magnitude in the mean. In order to extend this scale to fainter stars, the magnitudes of some stars coming within the range and region to be investigated must be determined first, and used as standards to carry on the scale still further.

In the preparation of the Harvard polar sequence of stars, methods (a), (b), (c), (d), and (e) were all used in order to render the scale absolute; the magnitudes of 96 stars are given, ranging from $4^m.5$ to 21^m (*Harvard Circular*, 170, 1912). Thirteen instruments and over 300 photographs were used, and the average deviation, for 48 stars brighter than the fifteenth magnitude, is $\pm 0^m.07$. The scale has been carefully tested, using the methods (b) and (c), by Professor Seares at the Mount Wilson Observatory, from the fifth to the fifteenth magnitude; from the tenth to the fifteenth magnitude the scale has been verified to within less than $0^m.05$, and the whole difference in measured range from the fifth to the fifteenth magnitude, between the Mount Wilson and the Harvard determinations, is only $0^m.3$. The Harvard polar sequence, consequently, furnishes an extremely accurate and valuable basis for photographic photometry in the northern hemisphere; and other sequences on the same scale, and in equatorial regions, are being formed at Harvard to enable the scale to be used in the southern hemisphere also.

At Göttingen the magnitudes have been determined of 3522 B.D. stars, mostly brighter than, and complete down to, $7^m.5$ in the zone 0° to $+20^\circ$ declination. Overlapping plates were used with three exposures in the ratio 1 : 3 : 9, the images being extra-focal, and the stars being compared by measures of greyness. The three exposures were used for convenience as an intermediary in fixing the magnitude scale, the interval between each being at first taken as approximately equal to one magnitude; the scale was subsequently corrected for systematic errors of all kinds, so as to render it the same over the whole region, and it was then rendered absolute by the grating method (c), and reduced to the international Astrographic scale zero.

Parkhurst, at Yerkes, has determined the photographic magnitudes of all the stars down to $7^m.5$ within 17° of the Pole, using method (g), and reducing the magnitudes to the Astrographic zero.

At Greenwich the magnitudes of all the stars down to $9^m.0$ and within 5° of the pole have been determined (*M.N.*, 72, 693, 1912) by direct comparison with the Harvard scale, using star-diameters as the basis for comparison.

In the last three photometric investigations the probable error of a magnitude determination from a single plate is about $0^{\text{m}}.07$, which is extremely small. The systematic difference between Parkhurst's and Schwarzschild's photographic magnitudes, which are supposed to be both on the same scale, does not exceed $0^{\text{m}}.05$ for stars brighter than $7^{\text{m}}.5$; the fainter stars were not so well determined, as the methods were not designed to do this. The systematic difference Parkhurst - Greenwich over the range $5^{\text{m}}.5$ to $7^{\text{m}}.5$ is $+0^{\text{m}}.13$, while the difference Schwarzschild - Greenwich over the range $6^{\text{m}}.0$ to $8^{\text{m}}.0$ is $+0^{\text{m}}.10$; hence the International and Harvard magnitude scales have almost the same zero point.

S. C.

Astrographic Chart and Catalogue.

During the year 1912 sections of the Astrographic Catalogue have been published by the Observatories of Bordeaux, Catania, Perth (Western Australia), Potsdam, and Toulouse. Adding these to the sections previously published, the following table is formed to show the actual state of publication:—

Observatory and Zone.		No. of Plates in Zone.	No. of Plates Printed.	Details of Catalogue.		
Greenwich	90° to 65° N.	1149	1149	Rect.-Co-ords.,	Diams.,	Plate-Constants.
Rome	64° „ 55° „	1140	54	„	Photo. Mags.	
Catania	54° „ 47° „	1008	60	„	Photo. Mags.,	R.A. and Dec.
Helsingfors	46° „ 40° „	1008	252	„	„	„
Potsdam	39° „ 32° „	1232	309	„	„	Constants.
Oxford	31° „ 25° „	1180	1180	„	Diameters,	„
Paris	24° „ 18° „	1260	540	„	Photo. Mags.,	„
Bordeaux	17° „ 11° „	1260	540	„	„	„
Toulouse	10° „ 5° „	1080	320	„	„	„
Algiers	4° N. „ 2° S.	1260	280	„	„	„
Perth	32° S. „ 40° S.	1376	80	„	„	„

As is mentioned on another page of this Report, a catalogue of Right Ascension and Declination is being formed from the measured co-ordinates of the brighter stars in the Greenwich section. This will also comprise the photographic magnitudes of these stars. Mention may also be made of a small volume issued from Greenwich during the year giving the rectangular co-ordinates, the pole being origin, of 2212 stars within 3° of the North Pole, which is actually a digest or summary of 41 plates in Volume II. of the Astrographic Catalogue. A volume of discussion of the Oxford Catalogue is being printed. The reduction of the Rome section of the Catalogue has been undertaken at the Oxford University Observatory.

As to the progress of the remaining zones, the printing of the

catalogue has been begun at the Cape of Good Hope (Zone 41° to 51° S.) and the state of the work will be found on the Report from that Observatory on another page. The progress of the zone undertaken by the Perth Observatory will perhaps be hindered by the transference of Mr. Cooke to the Directorship of the Sydney Observatory, and for the same reason the work at Sydney may be reorganised. Hitherto, the plates taken at Sydney (Zone 52° to 64° S.) have been measured and reduced at Melbourne, together with the plates (Zone 65° to 90° S.) allotted to the last-named Observatory.

At San Fernando (3° to 9° S.) and at Tacubaya (10° to 16° S.) the reduction is proceeding, but as yet no section of the catalogue has been published. No report of the work at Cordoba has been received since the appointment of Professor Perrine to the Directorship.

Tome vii., Premier fascicule of the Bulletin of the Permanent Committee, which has been recently published, consists of a list of 6163 stars chosen by Professor Küstner as *intermediate stars* to be observed by meridian instruments, in conformity with the scheme initiated at the Paris Conference in 1909, for the formation of an accurate catalogue of reference stars. The *Standard* stars chosen by Professor Backlund are also included and suitably indicated in this list.

The following table shows the total number of enlarged reproductions of chart plates distributed by the different observatories up to the end of the year 1912:—

Algiers	414	San Fernando	366
Bordeaux	201	Tacubaya	303
Brussels	9	Toulouse	254
Paris	444		

It has already been reported that the distribution of the Greenwich Chart is completed.

H. P. H.

Star Catalogues.

A catalogue of 8337 stars between $9^{\circ} 50'$ and $14^{\circ} 10'$ of S. declination (in 1855) for the equinox 1900, observed with the 8-inch meridian circle of Harvard College Observatory during the years 1888 to 1898, was published in the year 1912. This is one of the Astronomische Gesellschaft zone catalogues added to the original number to cover the sky from 2° to 23° of S. declination. The whole series of catalogues is now complete from 80° N. to 16° S. declination, the zone 70° to 75° N. originally allotted to Dorpat having been filled by the catalogue known as Berlin C. This Harvard catalogue is, as to the body of the work, of the same form as the others of the series. The general plan of the work was strictly differential, the basis of the reduction being of course the catalogue of fundamental stars prepared by Dr. Auwers for the southern catalogues and published by him in *Astronomische*

Nachrichten, 2890-91. Systematic corrections with argument magnitude, derived from comparison of the places of this catalogue with those of the Vienna and Washington catalogues, were applied in forming both the Right Ascension and Declination.

A catalogue of 9842 stars or all stars very conspicuous to the naked eye.—This catalogue, compiled and published by Mr. T. W. Backhouse, is a magnitude catalogue subsidiary to a series of star-maps which is being prepared for the use of meteor observers. In these maps it is considered necessary to include every object in the sky just within the range of unaided vision and to exclude all fainter objects; hence this catalogue was prepared by collecting the magnitudes of the stars in all available naked-eye Astrometries and by combining with these the magnitudes of the same stars as given in accurate photometric catalogues to derive a mean adopted magnitude for each star.

The magnitudes determined by naked-eye observation are those of Heis' expansion of Argelander's *Uranometria Nova*, Behrmann's *Stern-Verzeichnis*, Houzeau's Catalogue and Atlas, and Gould's *Uranometria Argentina*, and those by the Harvard observers made by naked eye or opera glass given in vol. xiv. of the *Harvard Annals*. The Harvard Photometry and other volumes of the *Harvard Annals* are the chief accurate photometric catalogues used, and the Harvard scale is taken as standard. The *Uranometria Nova Oxoniensis*, the Bonn *Durchmusterung*, the first Radcliffe Catalogue, and Stone's Cape Catalogue are also used in the compilation.

In the pages of the catalogue the stars are collected by constellations, and in the separate columns of the catalogue the Bayer letter, the Flamsteed number, and the number in some other catalogues are affixed to each star. Its magnitude in each of the above authorities in which it occurs is given, and with these the adopted magnitude, which is the purpose of the catalogue, found from the data according to rules given in the introduction. Approximate Right Ascension and Declination (1900), taken from one of a list of authorities duly specified, are added. In many cases two or more close stars are considered as seen as one by the naked eye, and their magnitudes combined, which brings many stars individually fainter than 6.5 within the limits of the catalogue.

Second Argentine General Catalogue.—A catalogue of the Right Ascensions and Declinations of 5791 stars derived from observations made with the 5-inch Repsold meridian circle of the Cordoba Observatory has been recently distributed. The Introduction is signed by Professor C. D. Perrine, and is dated 1911 February 25.

The observations were made during the years 1885 to 1890, and the places are reduced to epoch 1900, the whole process of reduction being precisely the same as that adopted for the previous Argentine General Catalogue, which was published in 1886, and contained more than 33,000 stars. In the present catalogue, the number of stars of south declination is 5723, among these being 63 comparison stars for the planet Victoria observed in 1889, and

68 northern stars mainly from the first Radcliffe catalogue. The columns of the catalogue give Right Ascension to hundredths of a second of time, and declination to tenths of a second of arc with precession and secular variation for these co-ordinates. A comparison of the places of this catalogue was made with those of Boss's Preliminary General Catalogue, and differences varying with magnitude were found corresponding closely to Boss's general value of the magnitude equation $-0^s.0069(M - 3.5)$, but corrections of this nature were not applied in forming the catalogue. H. P. H.

Stellar Spectroscopy in 1912.

The most prominent place in this year's report on stellar spectroscopy may fairly be given to an advance which in a certain sense does not come within the scope of the report. Professor Fowler has succeeded in observing, in laboratory experiments, not only the Principal hydrogen series, but also three lines in the Sharp (ζ Puppis) series and three lines of an ultra-violet series which has not previously been suspected (*M.N.*, **73**, 62). This constitutes an advance of great interest to astronomers. His success is a triumph of well-directed experimental work. It throws light in a crucial manner on alternative views in the numerical analysis of line spectra, and inasmuch as it has resulted in the discovery of the lines predicted by Rydberg as appropriate to the Principal series of hydrogen, it favours Rydberg's view very strongly; and at the same time it gives new weight to the work of Ritz. The fact that these hydrogen lines, which have so long eluded the efforts of physicists, have been evoked in the spectrum of hydrogen prepared from cleveite and therefore mixed with helium, may be significant; and accordingly it gives reason for hope that a clue may be found to several mysterious celestial and molecular phenomena of special interest. Professor Fowler's success comes at a very opportune moment; for the line at 4686, the brightest of the lines now definitely assigned to hydrogen, has lately been prominent in several ways. Dr. Nicholson shows that this line and another at 3728 are the only lines which remain unaccounted for in his work on the nebular spectrum (*M.N.*, **72**, 176).

Nebulæ.—Interesting phenomena are reported by Dr. Max Wolf in the spectrum of the Ring Nebula in Lyra (*Sitzb. Heid. Akad.*, 1911, No. 27). The spectrum of the outer ring exhibits the lines of nebulium, and the Diffuse series of hydrogen; that of the fainter part within the ring is specially marked by the strength of the line 4686, and that of the outer edge of the ring shows the line 3728 relatively strengthened. These facts point to a specialised distribution of matter or of peculiar conditions in the nebula.

A line at wave-length 4353 was predicted by Dr. Nicholson as a result of his studies of related frequencies in the nebular spectrum. This line has been found in the spectrum of the

Orion Nebula by Dr. W. H. Wright and by Dr. Max Wolf (*M.N.*, **72**, 693).

MM. Fabry and Buisson (*Jour. d. Phys.*, 1912 June) have applied interferential methods in a beautiful manner to the study of the widths of spectral lines as affected by the temperature and molecular weight of the gas in which they originate. They conclude from their observations that the widths of narrow lines conform with expectations based on the kinetic theory of gases. They fail to find evidence of dissociation or elevated temperatures in enhanced (spark) lines. They find that the width of the lines (except H and K) in the solar spectrum is appropriate to the generally accepted temperature and pressure of the Sun. Applying this method to the light of the Orion Nebula, they conclude that their results proving the existence of interferences of the order 10^4 are not favourable to the hypothesis of elevated temperature.

Novæ.—The following references serve as a guide to information about the spectrum of *Nova Geminorum* No. 2, which was discovered by Enebo on 1912 March 12:—

Enebo,	<i>Ast. Nach.</i> , 191 , 31,	(Telegram); 191 , 65, note of discovery.
Pickering,	„ 191 , 31,	Earliest spectrum, of type F5. 191 , 101, early changes.
Schwarzschild,	„ 191 , 50,	Broad lines with large displacements, and narrow lines with small displacements.
Wolf,	„ 191 , 66,	Map of field of Nova. 191 , 167, indications of periodic changes.
Rosenberg,	„ 191 , 120,	H α photographed; no polarisation.
Küstner & Giebeler,	„ 191 , 393,	Spectrum of radium, suspected.
Kayser,	„ 191 , 422,	Radioactive processes in Novæ.
Furuhjelm,	„ 192 , 117,	Titanium and scandium lines, March 15-22.
Ludendorff,	„ 192 , 123,	Measures of weak absorption lines, March 15.
Lau,	„ 192 , 240,	Early visual observations.
Stratton,	„ 192 , 244,	Visual observations on August 13.
R. H. Curtis,	<i>Ap. J.</i> , 35 , 233,	Early spectra, March 13-19.
Adams & Kohlschutter,	„ 36 , 293-321,	Spectra, March 22-May 27 (13 nights). (Photographic reproductions of spectra). No polarisation.
Newall & Stratton,	<i>Obser.</i> , 1912, 172,	Early spectra with slit spectrograph.
W. E. Curtis,	<i>M.N.</i> , 72 , 511,	Early spectra with objective prism.
Greenwich Observatory,	„ 72 , 516,	Early spectra.
Espin,	„ 72 , 708,	Visual observations.
Becker,	„ 72 , 709,	Table of wave-lengths from 3845-6817, March 15.
Cortie,	„ 72 , 714,	Spectrogram of April 24.
Pickering,	<i>H.C.O.</i> , Circ. 176,	Summary of changes, March 13-June 6 (36 nights).
Plaskett,	<i>R.A.S. Can.</i> , 6 , 27,	Spectrograms of March 18-29.
Stratton,	<i>M.N.</i> , 73 , 72,	Spectrum in December.

The spectrum of P Cygni, which is still similar in many respects to the spectrum of a Nova, has been photographed by Professor Frost (*Ap. J.*, **35**, 286) at intervals since 1904. These observations, together with those of M. B  lopolsky (*Ap. J.*, **10**, 319), show that no considerable change either in the nature of the spectrum or in the velocity deduced from the displacements has taken place in nearly thirteen years.

Study of Stellar Motions and Classification of Spectra.—Dr. Campbell (*L.O.B.*, **7**, p. 19, No. 211) gives a table of preliminary radial velocities of 212 bright stars of Class A, and states in concise form the results of the study of these velocities, carried out on lines similar to those previously adopted for stars of Class B. The results are referred to in the note on Stellar Distribution and Drift (*supra*, p. 288). H. C. Plummer (*L.O.B.*, **7**, p. 30, No. 212), dealing with a large part (172 stars) of the material used by Dr. Campbell, discusses it from a somewhat different standpoint. The general result of these discussions seems to indicate the need for caution in generalisation based on the material now available. The addition of new material to the extent of 20 per cent. modifies considerably the earlier conclusions, and the knowledge that several observatories are taking steps to increase the available material by modifications of spectrographic methods is very welcome.

H. C. Wilson (*L.O.B.*, **7**, p. 48, No. 214) discusses the real motions of 100 stars of large proper motion and summarises his results in four very instructive diagrams.

Spectral Studies of the Milky Way and of Special Stars.—A region of the Milky Way, regarded as a luminous surface, would probably by most astronomers be expected to give a spectrum of Sirian type. E. A. Fath (*Ap. J.*, **36**, 362) makes a direct frontal attack on the problem and gets results which are interpreted as a spectrum of solar type. A spectrum obtained under the conditions specified offers no little difficulty of interpretation. Since no lens is used to throw an image on the slit, and since consequently there is no phase relation between the small beams (of width no larger than the slit, viz. 0.8 millimetre) incident on the collimator lens from the individual stars, it would appear that the effective resolving power of the instrument used was of the order 100, and the purity at most about 60, and probably much lower. This power is barely sufficient to separate the H and K lines. It is risky to base any judgment on the enlargements reproduced in the plate accompanying Mr. Fath's paper; the appearances seem capable of being interpreted rather as those of a spectrum of Sirian type. The observation is of so much interest that it is desirable that the method should be put beyond doubt.

The spectrum of R Cygni has been studied visually by Dr. Espin (*M.N.*, **72**, 546), and has been photographed and measured by Dr. Wright (*M.N.*, **72**, 548).

The visual parts of the spectra of γ Andromedæ, α Cassiopeiæ, α and γ Cygni, and α Persei have been studied photographically at Potsdam by Herr Hnatek (*Ast. Nach.*, **190**, 273).

The system of the variable star Algol has been further studied by M. Bèlopol'sky (*Bull. Acad. Imp. St. Pet.*, 1912, 937) with results that bear upon the existence of a dispersion effect in space.

Radial Velocities.—The detailed results of the D. O. Mills Expedition, under Dr. W. H. Wright, to the Southern Hemisphere, up to March 1906, are set forth in the Publications of the Lick Observatory, vol. **9**, part iv. The velocities of 150 stars south of declination -20° are given in a catalogue at the end of the volume; together with a list of 41 of them having variable velocity, and details of the orbits of α Carinæ, α Pavonis, and κ Velorum deduced by H. D. Curtis.

Variable Radial Velocity—Notes on variability of velocity are given for the following stars:—

δ Andromedæ	Campbell	<i>L.O.B.</i> , vii. 102
μ Cephei	"	" "
ζ Horologii	Moore	<i>L.O.B.</i> , vii. 96
A Velorum	"	" "
η Velorum	"	" "
f Velorum	"	" "
L Carinæ	"	" "
l Centauri	"	" "
Q Scorpii	"	" "
ν_2 Sagittarii	"	" "
λ Telescopii	"	" "

For the star ι Capricorni, which was in 1906 announced as having variable velocity, Professor Campbell (*L.O.B.*, vii. 102) now states that the removal of some errors of reduction leaves the velocity apparently constant at $+12$ km/sec.

A list of 50 stars, mainly of types A and B, is given by W. S. Adams (*Ap. J.*, **35**, 172) as having been found, in one year's work at Mount Wilson, to have variable velocity. The same paper contains a list of 7 stars with large radial velocities ranging from 96 to 175 km/sec. This list contains stars chiefly of solar type and of magnitudes $5.2-8.0$, and since each of the stars has a well-determined parallax and proper motion, it is possible to deduce the magnitude and direction of the velocity in space. The paper is remarkable not only for its conciseness of statement of the results obtained in one year's work, but also for the nature of the results, which carry stellar spectroscopy into a new field of research.

Spectroscopic Binary Stars.—Orbits are given for the following binary stars:—

β Scorpii	Daniel & Schlesinger	<i>Alleg. Obs.</i> , 2 , 127	6.8 days.
„	Duncan	<i>Lowell Obs.</i> , 2 , 21	
θ_2 Tauri	Plaskett	<i>R.A.S. Can.</i> , 6 , 231	140.5 „
θ Aquilæ	Harper	„ 6 , 265	17.12 „
γ Geminorum	„	„ 6 , 179	2175 „

Herr Ludendorff (*Ast. Nach.*, **192**, 447) publishes observations relating to γ Geminorum, and it is clear that there are peculiarities in the velocities recorded for this star.

The star ϕ Persei still attracts considerable attention. It is of binary character, of period 126.6 days, with bright hydrogen lines with central dark reversals; and it is one of the stars that show peculiarities in the displacements of the calcium lines H and K. Herr Ludendorff (*Ast. Nach.*, **192**, 173) discusses observations made by himself and by Mr. Cannon, and concludes that the displacements of the hydrogen lines do not exactly correspond in successive periods. Mr. Merrill (*L.O.B.*, vii, 97) finds that in spectrograms of the spectral region 4340–6600 many bright lines appear, corresponding in several cases with strong lines in the solar chromosphere. The spectrum has been usually regarded as belonging to Class B.

For the star α Persei Herr Hnatek (*Ast. Nach.*, **192**, 245) has deduced an orbit from all the observational material at Potsdam between the years 1900 and 1908. The adopted period is 4.09 days; in approximate agreement with Newall's first period 4.20, but in disagreement with Goos's period of 290 days. Mr. Pitman (*L.O.B.*, vii, 99) reviews the evidence and concludes that the velocity is either constant or only minutely variable in a period still undetermined.

In the orbit of 30 H Ursæ Majoris Mr. Schlesinger (*Alleg. Obs.*, **2**, 139) finds signs of a secondary oscillation.

In the orbit of Y Ophiuchi, Miss Udick (*Alleg. Obs.*, **2**, 151) finds no evidence of the secondary oscillation suspected by Albrecht. The same writer deduces the orbit of B.D. + 43° 92, a star of class A₂ (*Alleg. Obs.*, **2**, 191).

Herr Ludendorff (*Ast. Nach.*, **193**, 301) discusses the relation between amplitude of brightness and radial velocity in Cepheid variables; and Mr. Brunt (*Observatory*, 1913, p. 59) gives a useful summary relating to these systems.

Tables.—Mr. Schlesinger and Miss Udick (*Alleg. Obs.*, **2**, 155) have compiled tables for the true anomaly in elliptic orbits to facilitate the computation of the orbits of spectroscopic and visual binaries.

Instruments.—Mr. Adams (*Ap. J.*, **35**, 163), in a remarkable paper already referred to, describes the three-prism stellar spectrograph of the Mount Wilson Observatory.

In the first part of volume i. of the Publications of the Detroit Observatory, a description is given of the recently completed reflector of aperture $37\frac{1}{2}$ inches, and Dr. R. H. Curtiss gives details of the single-prism spectrograph which has been attached to it.

Dr. Schwarzschild (*Sitzb. d. K. Preuss. Akad. d. W.*, **53**, 1220) discusses the requirements for spectrograph objectives, and describes a new form, of ratio 1:4.5, and therewith indicates a solution of wide applicability.

H. F. N.

Gylden's "Traité des Orbites Absolues," Vol. II.

In 1893, Gylden published the first volume of his *Traité des Orbites Absolues des Huit Planètes Principales*. This work, as is well known, had not the main object of furnishing new determinations of the orbits of the planets suitable for comparison with observation, or for making tables similar to those deduced from the theories of Leverrier and Newcomb. The object was rather an attempt to obtain, in a periodic form, what the author calls "absolute" orbits of the planets; these orbits may be defined loosely as the orbits freed from the short-period terms and containing all long-period terms. Hence an absolute orbit of a planet at any date may be considered as the average orbit during a few revolutions before and after that date, this average being available over long periods of time.

The main difficulty that arises is due to the divergence of the series of periodic terms. Ordinarily we do not let the question enter, for we expand the terms of very long period in powers of the time and thereby limit the time-interval of application. Gylden wished to extend this interval, indefinitely if possible, and for this it was necessary to retain the periodic forms in all cases. That he did not succeed is not a criticism of his method but rather a defect of all methods which employ sums of harmonic terms, as Poincaré has proved. Whether it is possible to obtain convergent expressions for the co-ordinates, or whether the motions are essentially unstable is still an open question.

At the outset, the methods of Gylden bore some resemblance to those of Hansen, but later, with the idea of abandoning the Keplerian ellipse, he devised plans of his own which have been adopted and employed by many of his pupils for various researches, both theoretical and numerical. These methods have two unfortunate defects: they are extremely complicated to anyone not thoroughly familiar with them, and it is difficult to connect them with the other methods which have been employed. This latter defect becomes troublesome in computations of the orbits of certain asteroids when the principal perturbations are by no means numerically fixed, and it is desired to make comparisons. Nevertheless, the forms which he gives to his equations are based on theoretical and practical considerations and were certainly devised with an intimate knowledge of the defects of other theories.

Another idea which is fundamental for a proper appreciation of his work on the major planets was his desire to obtain expressions available over considerable periods of time for the orbits of the asteroids. These bodies are so sensitive to the influence of the nearer planets, especially Jupiter, that the perturbations of long period frequently become very large. In order to obtain these with an accuracy which shall make it possible to predict their positions with reasonable certainty for more than a few decades, a more extensive knowledge of the long-period oscillations of the major planets than is given by the theories in existence is necessary. Herr Brendel's researches on the small planets in fulfilment of this idea are already far advanced.

In the first volume referred to above the theoretical investigations and algebraic developments are made. The second volume, which appeared in 1909, consists mainly of the reduction of the formulæ to numbers for the cases of the eight principal planets. Only a portion of the work was completed at the time of Gylden's death; Dr. Backlund, with the assistance of MM. Sundman and Zeipel, have published this portion and have completed it to a certain stage. The numerical values of the coefficients in the developments of the disturbing functions and the forces are now given for each pair of planets, so that they are ready for substitution in the differential equations of motion.

The labour of verifying portions of these and of completing them without a full knowledge of the route which Gylden had intended to follow largely accounts for the long interval between the two parts of the work. Anyone who may wish to continue it on the lines laid down will feel grateful that he may start with so much of the labour already performed. It may, perhaps, be compared with the position of one using the method of the variation of arbitrary constants and finding ready at hand the full development of the disturbing function given by Leverrier and Boquet in the *Annales de l'Observatoire de Paris*. E. W. B.

On the Theory of Radiation.

The recent investigations discussed in the present note have a wider importance than their titles might seem to indicate: their main interest lies in the fact that they create a very strong presumption, amounting in the opinion of many to absolute proof, that the Newtonian laws of mechanics and the Maxwell laws of electromagnetism must be abandoned in favour of more general laws. The old laws appear to give valid approximations to the truth for matter in mass, but cease to give even a tolerable approximation when applied to certain problems of molecular physics. The existence of a new natural unit is disclosed—a unit of action (energy $\times$ time) of amount approximately 6.6×10^{-27} erg $\times$ secs—and the old laws appear to fail utterly for processes in which the total action is so small as to be comparable with this unit.

A dynamical system, shielded from loss of energy and left to itself, must after an adequate time assume a final state depending only on the total energy of the system. If the motion of the system is determined by the principle of Least Action (a principle which includes the laws of Newton and Maxwell), then this final state can be shown to possess certain very simple properties, chief of which is that of equipartition of energy. The validity of the theorem of equipartition, due originally to Maxwell and Boltzmann (1859, 1861), is no longer seriously disputed; there is now universal agreement among competent investigators that, given conservation of energy and least action, equipartition must necessarily follow (Lorentz, Poincaré, Planck, etc.; *La Théorie du Rayonnement*, Gauthier-Villars, 1912). This requires, in particular, that all the vibrations of the system, of whatever nature or wave-length, must, on the average, possess equal amounts of energy. At temperature T° abs., the average energy of each vibration must be RT where R is the universal gas-constant.

It is known (*Phil. Mag.*, 1909 Feb.) that in a unit volume of any medium capable of vibration, the number of independent vibrations of wave-lengths between λ and $\lambda + d\lambda$ is $c\lambda^{-4}d\lambda$, where $c = 4\pi$ for sound-waves in a gas, $c = 8\pi$ for light-waves in ether, and $c = 12\pi$ for elastic waves in a solid. This formula is true down to values of λ comparable with the scale of structure of the medium, after which it fails. It follows that the law of partition of vibrational energy in any medium ought to be

$$cRT\lambda^{-4}d\lambda \quad . \quad . \quad . \quad . \quad (\text{i})$$

this expressing the amount of vibrational energy per unit volume of wave-length between λ and $\lambda + d\lambda$. As the value of expression (i) increases very rapidly when λ decreases, it is clear that if the medium obeys the principle of least action, its energy must tend mainly to run into the shortest vibrations of which the medium is capable—each individual vibration has the same energy RT , but the short vibrations preponderate enormously in number.

An illustration is provided by the consideration of a disturbance in a finite gaseous medium (*e.g.*, a room or a stopped organ-pipe). Any set of initial waves tends to degenerate into the well-known random heat-motions of the molecules (Maxwell's law). Such a system of random motions can be analysed into regular waves by Fourier's theorem, and the resulting partition of energy at temperature T is found to be (*Phil. Mag.*, 1909 Feb.)

$$4\pi RT\lambda^{-4}d\lambda,$$

confirming formula (i) exactly.

Briefly, then, heat in a gas is the same thing as sound, but mainly sound of very short wave-length. For the rest, this illustration suggests that the theorem of equipartition, when applied to a medium capable of vibration, indicates little more than a general tendency for regular vibrations to degenerate into random motions, or for mass motion to dissipate into heat. Further obvious in-

elastic solid medium at temperature T to be vibratory energy per unit volume

$$12\pi RT\lambda^{-4}d\lambda \quad . \quad . \quad . \quad . \quad (iv)$$

of wave-length between λ and $\lambda + d\lambda$, originating in the elastic vibrations—*i.e.* in waves of sound in the solid. This energy ought to be found for values of λ down to λ_0 , where λ_0 is a limit fixed by the coarse-grainedness of the solid, and so comparable with atomic distances. Integrating, the total energy of sound-waves in the solid ought to be $4\pi RT\lambda_0^{-3}$, or $3NRT$, where N is the number of atoms per unit volume. It follows that sound-waves in the solid ought to give a contribution $\frac{3NR}{J\rho}$ or $\frac{3R}{Jm}$ to C_v , the specific heat of the solid at constant volume.

The recent experiments of Nernst, Lindemann, and Koref (*Preuss. Akad. d. Wiss.*, 1910; *Ann. d. Physik*, 1911) have shown that $\frac{3R}{Jm}$ is exactly the *total* value of C_v for a great number of substances

at moderate temperatures. The formula $C_v = \frac{3R}{Jm}$ contains the law of Dulong and Petit and predicts a uniform atomic heat of 5.95 *at constant volume*, which appears from these experiments to be exactly the true value for wide ranges of temperature.

At lower temperatures the formula fails completely, but the observed values of C_v are in almost perfect agreement with the theoretical formula recently published by Debye (*Ann. d. Phys.*, 1912). Debye assumes that the energies of the different sound-waves are not all equal, as they would be according to Newtonian mechanics, but vary in the same way as the energies of the different light-waves in Planck's formula. The energy of a vibration of frequency ν is assumed to be not RT , but $RT \times \frac{x}{e^x - 1}$, where x , as before, stands for $h\nu/RT$; thus the total energy of elastic solid vibrations is taken to be (*cf.* formula (iv))

$$\int_{\infty}^{\lambda_0} 12\pi RT \frac{x}{e^x - 1} \lambda^{-4} d\lambda,$$

and the corresponding contribution to the specific heat follows on differentiation with respect to T . Debye (*l.c.*) finds that the formula so obtained agrees exactly with the total values of C_v given by the very comprehensive experiments of Nernst and his colleagues.

This result of Debye is of far-reaching importance. Virtually it shows heat in a solid to be precisely identical with sound. Warming a violin string sets up exactly the same motions as stroking it with a bow. In general, the proportion in which the different harmonics enter is not the same in the two cases, but it is a startling and noteworthy consequence of Debye's formula that at the lowest temperatures the heat energy of the string resides

entirely in its fundamental note and lowest harmonics. Incidentally, Debye's result diminishes greatly the supposed importance of the free electron. It now appears that there are not enough free electrons in a solid to contribute perceptibly to the specific heat, and hence far too few to account for the conduction of heat or electricity.

From all this it will be seen that there is very firm experimental ground for believing the ultimate structure of the universe to be such that the energy of a vibration in the steady state is not RT , but $RT \times \frac{x}{e^x - 1}$. (Planck's law). The problem of finding a system of dynamical equations which will lead to this law is of course a purely theoretical one.

It can be shown that if the motion of the universe is governed by any system of differential equations whatever, equipartition of energy must result. The ultimate motion of the universe must therefore be in some way discontinuous (Jeans, *Phil. Mag.*, 1910). To obtain Planck's law, it can be proved to be necessary that energy itself should be atomic, at least as regards vibratory energy (Jeans, *l.c.*, 1910; Poincaré, *Journ. de Phys.*, 1912); energy of frequency ν must occur only in integral multiples of an indivisible unit $h\nu$, where h is the new universal constant 6.6×10^{-27} erg $\times$ secs. The energy of any vibration must jump instantaneously and without transition from $n h \nu$ to $(n \pm 1) h \nu$. The unit is a large one; for yellow light it is about equal to the kinetic energy of 15 molecules of air at 0° C. In this connection reference must be made to experiments on the photo-electric effect (especially Hughes, *Phil. Trans.*, 1912). It has long been known that electrons are expelled from the surface of a metal exposed to ultra-violet light. To dissociate an electron from the metal to which it belongs requires an amount of energy, ϵ , which varies from metal to metal. Roughly speaking, it now appears that light of frequency ν will only cause electrons to be ejected if the frequency is so great that $h\nu > \epsilon$. Moreover, if expulsion occurs, the energy absorbed from the incident radiation is not ϵ , but is $h\nu$, the excess energy $h\nu - \epsilon$ appearing as kinetic energy of the electron! Certainly this appears to countenance the view that radiant energy of frequency ν can occur only in indivisible units $h\nu$. On the other hand, such a view runs counter to many established results of the undulatory theory of light—to take one instance, a small telescope ought to have resolving power equal to that of a large one; fewer units would enter the tube, but each would be just as perfect as if the telescope were larger. And the experiments of Taylor (*Camb. Phil. Soc. Proc.*, 1907) on the photography of faint interference bands seem to prove that light can exist in amounts far less than the indivisible unit $h\nu$ demanded by theory. Thus it has come about that although analysis has shown that the observed radiation law (Planck's law) necessarily requires the quantum-theory of energy, yet this quantum-theory is universally rejected by physicists.

Poincaré (*Journ. de Phys.*, 1912) has shown that if Planck's formula for spectral energy is nearly but not quite true, then the quantum-theory must be nearly but not quite true. From the mere fact that the radiant energy emitted at finite temperature is finite, some kind of discontinuous motion may be inferred (Poincaré, *l.c.*). There is therefore no escape from the quantum-theory of energy by appealing to errors of observation.

Planck, who originated the energy-quantum theory, has recently withdrawn it in favour of a new theory, based on the conception, not of an indivisible atom of energy $h\nu$, but of an indivisible atom of action h . An atom of action is not easily imagined, or reasoned about, and many physicists object to Planck's newer theory on the ground that it is inconsistent with itself (Poincaré, *l.c.*).

One of the phenomena of modern physical thought is the rapid growth of the school, now comprising many of the foremost German physicists, who find reasons for disbelieving the existence of the ether. The abandonment of the ether appears, however, to do little more than shift the fundamental difficulty of the present problem. Debye's formula for specific heats shows that the difficulty would immediately reappear in connection with matter, even if it could be successfully avoided in connection with the ether.

Finally, there occurs the question of whether the universe ought justly to be regarded as a mechanical system at all. Vague questionings on this ground have been crystallised by Poincaré (*La Science et l'Hypothèse*), who put forward the suggestion that there may be several ways of approaching the study of nature. The Newtonian standpoint, which views all material phenomena in terms of forces, accelerations, etc., may not be the only legitimate standpoint—indeed, may not be a legitimate standpoint at all. It may be that the solution of the present difficulties is to be found by approaching the study of nature from an entirely new direction. In any case it seems quite possible that the near future will demand an extensive revision of our ideas of the nature of time and space, and of the relation between them which we think of as motion: to many such a revision seems already to be inevitable.

J. H. J.

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ADDRESS

Delivered by the President, F. W. Dyson, M.A., LL.D., F.R.S., on presenting the Gold Medal of the Society to M. H. A. Deslandres.

THE Council have awarded the Gold Medal to M. Henri Alexandre Deslandres for his "Investigations of Solar Phenomena and other Spectroscopic Work." It is my pleasant duty to place before you the grounds on which this award has been made.

Solar Physics may be fairly said to date from 1843, when Schwabe announced the periodicity of sun-spots. This great discovery was soon followed by another. The frequency of terrestrial magnetic storms was found to agree in period and phase with the extent to which the Sun is covered with spots. The parallelism of these two phenomena was so marked that it became clear that they must be connected with one another. A great impetus was thus given to the observation and study of sun-spots and of magnetic phenomena. Drawings of the Sun's surface each day were commenced at several observatories, and in due course photographs generally superseded visual drawings.

The next era opens in 1868 with the application of the spectroscope by Janssen and Lockyer to the study of Solar prominences, which till then were only observable at rare opportunities afforded by eclipses. From the rapidity of their changes prominences are in some respects more interesting than spots as subjects of observation. The limb of the Sun has been therefore studied daily in several observatories, both as regards the constitution and movements of individual prominences, and also statistically as regards numbers and distribution. By these studies prominences have been found to share in the great physical Solar oscillation, whose existence was first shown by Schwabe's observations of spots.

The third epoch in the history of Solar Physics is associated with the names of Hale and Deslandres. Through their genius the forms and movements of different layers of the Solar Atmosphere have been revealed to us. Almost simultaneously they attacked the problem of replacing the tedious and necessarily uncertain hand delineation of the forms of prominences by photography. Also they discovered in 1891 approximately simultaneously the reversal of the H and K lines on the Sun's disk, and realised the possibility of the application of the spectroscope to the study of the Solar Atmosphere over all the visible disk, and not only at its limb. The spectroheliograph was realised in actual practice first by Hale. But Deslandres has not only contributed greatly to its development, but he has also constructed another instrument, the "Spectro-Euregisteur des

Vitesses" or velocity recorder, which is of equal and may prove of even greater importance. Thanks to this discovery, we can follow and study the varying movements of the Solar Atmosphere, as well as the forms of the different layers.

Our Medallist's labours in Solar Physics have extended over more than twenty-one years. They began in 1891, when he was appointed by Admiral Mouchez to organise the Spectroscopic work of the Paris Observatory. Before his appointment he was distinguished as a Spectroscopist by very valuable work on "Banded Spectra," published in the *Comptes Rendus* in the years 1886-1891. He remained at the Paris Observatory from 1891 to 1898, and in addition to the Solar work which he initiated, he commenced work on Stellar Spectroscopy, and subsidiary researches in the laboratory. In 1898 he became Astronomer at the Astrophysical Observatory at Meudon, and organised the Spectroscopic work with the large equatorial. During this period he continued his work on Banded Spectra and made observations on Stellar Spectra, continuing all the time his solar researches. In 1906 he was appointed Assistant Director, and on the death of Janssen in December 1907 he became Director. He reorganised the solar outfit, with results shown in the remarkable volume iv. of the *Annales* of the Meudon Observatory. To this period belongs his work on the Spectra of Comets and their tails.

In the first place I shall put before you a very brief account of M. Deslandres' work on banded spectra. With a small dispersion the spectra of certain gases are found to consist of broad bands, sharp at one end and fading away gradually at the other. With a large dispersion these bands are separated into lines. Piazzi Smyth had analysed the green band of carbon monoxide, and Alexander Herschel had found that the wave numbers of the separate lines were in arithmetical progression. Beyond this nothing was known of the structure of banded spectra. The researches of Deslandres, in the words of Kayser, have brought our knowledge to a different plane. He has established the laws, very remarkable and simple, which all the spectra of this class obey.

The first band which he measured and discussed is one of those in the spectrum of nitrogen near the negative pole in tubes at ordinary pressure. The intervals between the separate lines, expressed in number of vibrations, or the inverse of wave-lengths, are in arithmetical progression. This law, which is now known as Deslandres' First Law, he found to hold for (1) each band of the negative pole of nitrogen; (2) the bands of the second group of the spectrum of nitrogen shown in the positive column, each of these bands being analysed into three series of lines with their intervals in arithmetical progression; (3) for the third group of bands in the positive spectrum (*w.l.* 3000 to 2000), each of these being separated in two or four series; (4) the cyanogen bands; (5) the telluric bands A, B, α , each giving two series; and (6) the bands of water vapour.

Thus the wave numbers of separate lines in the nitrogen band at 3914·6 are expressible by the simple algebraical formula

$$N = 255\cdot45 + \cdot0015335 (n - 1)^2,$$

which was verified for values of n from 1 to 63. In general each series of a band is such that the number of vibrations of the separate lines is given by a formula

$$N = Am^2 + a,$$

where A , a are constants and m takes successive integral values.

To this first law he adds the following:—The different bands due to the same body are all similar, and consist of the same number of component series. In other words, each band is formed by the repetition of groups of similar lines, such as doublets, triplets, etc.

In 1887 Deslandres took another step and found that just as the intervals between the wave numbers of separate lines in each component series are in arithmetical progression, so also are the intervals between separate heads of the same group. He first verified this law for the second group of nitrogen bands extending from $\lambda 5000$ to $\lambda 3000$, and remarkable for its great extent and regularity. There are fifty-two bands, and each band is formed by the superposition of three equal and equidistant arithmetic series. These bands are divided by Deslandres into five groups. The heads of all the bands in each group are found to be represented by a formula $Bn^2 + C$.

This is called by Kayser Deslandres' Third Law. It follows that the wave number of all lines of all bands are contained in the formula

$$N = \frac{1}{\lambda} = Am^2 + Bn^2 + C,$$

where m and n are integers.

This law Deslandres verified for the ultra-violet group of the positive spectrum of nitrogen, the heads falling into four series; for the negative spectrum of nitrogen, forming five series; the first group of the positive spectrum of nitrogen ($\lambda 7000$ — $\lambda 5000$), forming three series; the Swan spectrum; the spectrum of carbon dioxide, and finally the spectrum of iodine.

He went one step further. Taking the five series into which the heads of the second nitrogen group had been arranged, the constant C of the formula $N = Am^2 + Bn^2 + C$ was found to be $-134\cdot151$, $-152\cdot533$, $-171\cdot268$, $-190\cdot687$, and $210\cdot623$ in the five cases. The squares of these numbers give intervals which are in arithmetical progression. He thus finds that all the lines in all the bands of this complicated group can be represented by a formula

$$N = f(n^2, p^2)m^2 + Bn^2 - \sqrt{cp^2 + v}$$

where p , m , and n integers.

He compares the formula with that obtained mathematically for the elastic vibrations of a solid body. It is characteristic of him not to be content with the analysis of a very complicated medley of lines into an order of beautiful simplicity, but to consider also the bearing of his results on the structure of the molecule.

He pursued his researches on various spectra of carbon compounds, and gave an interesting application of the laws he had discussed to decide the question to what compound of carbon certain faint bands belonged. Working with gases at low pressures it is difficult, on account of the presence of impurities, to be sure to what source certain spectra should be attributed, carbon, cyanogen, hydrocarbons, carbon monoxide, or carbon dioxide. He concluded, from numerical relationships of these unknown bands with sixteen bands known to arise from hydrocarbons, that the unknown bands must have the same origin.

Deslandres laid aside researches on banded spectra for some years, but resumed them between 1902 and 1905. In the interval important papers by Kayser and Runge, Ames, Cuthbertson, and others confirmed the laws he had discovered and showed within what limits they held good. With greater dispersion than he had formerly employed, he studied the spectra of nitrogen and air. For moderately long series the law $N = A(m+n)^2 + C$ is satisfied, but when the series is very long, consisting of 50 lines or more, systematic differences are manifested.

Working on Cathode rays, he found that the banded spectra of gases excited in this way were specially simple. Comparison of spectra emitted under various conditions led him to the conclusion that the spectra of the positive pole, formed by the repetition of multiple lines, arise from molecules having several atoms; the spectra from the negative pole, on the contrary, arise from single atoms. When the Cathode rays which ionise the gas are sufficiently strong to render it luminous and give a band spectrum, they decompose it into its simplest chemical elements. Another interesting fact he brought to light is that as the pressure increases the bands become more complex.

In the year 1891 M. Deslandres was appointed by Admiral Mouchez to organise the spectroscopic work at the Observatory at Paris. In this great Observatory, which is mainly devoted to Astrometry, he organised Solar work, laboratory researches, and undertook the difficult observations of the determination of velocities of stars in the line of sight. He employed the photographic methods which had been introduced by Vogel, and introduced the use of the iron comparison spectrum instead of that of hydrogen.

During this period he determined the rotation of Jupiter spectroscopically by measuring the inclination of the lines of its spectrum to those of neighbouring terrestrial lines, the slit of the spectroscope being placed along an equatorial diameter of the planet. He obtained for the difference of velocity of opposite

points of the equator $48 \text{ km.} \pm 1 \text{ km.}$, whereas the calculated difference is 49.6 km. The same method had, without M. Deslandres' knowledge, been previously used at Greenwich, but the result obtained was far less accurate. He applied a similar method to Saturn and its rings, and later at Meudon in 1902 to the planet Uranus. Owing to the faintness of the planet and its low altitude at Meudon he was unable to determine the velocity of rotation with accuracy, but was able to say that the rotation was in the retrograde sense.

While at the Paris Observatory he made an expedition to Senegal to observe the total eclipse of 1893 April 16. He was successful in obtaining photographs of the Corona, and especially of the spectrum of the Chromosphere and Corona in the extreme ultra-violet. He also made the first attempt to determine spectroscopically the rotation of the Corona. For the 1896 eclipse, like many other observers, he made an expedition to Japan which was unsuccessful owing to unfavourable weather. In the eclipse of 1900, which he observed in Spain, he made observations similar to those of 1893, and also made a determination of the heat of the Corona. In his report in the *Comptes Rendus* he makes the interesting suggestion of the possibility of observing the heat radiations of the Corona without an eclipse. He was successful in obtaining the chromosphere spectrum as far as $\lambda = 3066$, and in discovering three new lines at wave-lengths 3329.6 , 3388.0 , 3447.7 in the spectrum of the Corona. In the eclipse of 1905 as in 1896 M. Deslandres was unfortunate in having cloudy weather during the period of totality.

M. Deslandres has made a series of interesting and important studies in the spectra of Comets and their tails. Beginning with Borelly's Comet of 1893, and continuing his researches on Daniel's Comet of 1907 and Morehouse's Comet of 1908, he has obtained spectra of the heads of the Comets and found in them bands due to hydrocarbons and to cyanogen. In addition, he found in Daniel's and Morehouse's Comets bands which stretched into the tail to the extent of as much as 8° . One of these he identified with the line given by nitrogen at low pressure at the negative pole, identical with a strong line found in the spectrum of the Aurora. The others were identified by Professor Fowler as due to carbon monoxide at low pressures.

I come now to the researches which your Council had specially in mind in awarding the Gold Medal to M. Deslandres, namely, his investigations of Solar Phenomena. These have occupied him for many years. They were pursued for a long time with small equipment and they have, when the opportunity offered, been magnificently developed. Soon after his appointment to organise spectroscopic work at the Paris Observatory, M. Deslandres recognised that the vapours of calcium projected on the Sun's disc are readily perceived photographically not only above spots but also above faculæ by bright lines which show themselves on the wide dark H and K lines of the Solar Spectrum; and further, that

these bright lines are double, being separated by a fine dark central line. This fact suggested to him the employment of two special forms of spectrographs with two slits. In one of these instruments the second slit is narrow and set so as to exclude all light except that of the bright K line, and then by suitable continuous movements to register the inequalities in the brightness of this bright calcium line over the whole of the Sun's disc. This instrument, successfully realised by Hale, shortly before Deslandres, is now well known as the Spectroheliograph. The other instrument, the Velocity Recorder, has a much wider second slit, so that for a given position of the first slit in the image of the Sun's disc a small region of the Solar Spectrum in the neighbourhood of the calcium line is photographed. By a series of discontinuous motions, the spectra of successive chords of the Sun's disc are photographed. Displacements of the central part of the K line in different parts of the Sun may be interpreted as indicating the velocity of the calcium vapour in the line of sight. This instrument is called by Deslandres the "*Spectro-Enregistreur des Vitesses*." The Spectroheliograph gives the forms of the calcium clouds in the Solar Atmosphere, or rather a record of the brightness of these clouds at a fixed wave-length; the Velocity Recorder gives another element which it is equally important to know, namely, the spectral displacements of the complete calcium line, which are interpreted as the movements of these calcium clouds. After his return from Senegal in 1893, aided by a grant of only £200, M. Deslandres proceeded to put these ideas into practice. I shall throw upon the screen spectroheliograms obtained with the bright K line on the 10th and 11th of April 1884. The objective was 4·8 inches, and a Foucault siderostat was used to reflect the Sun's image upon a stationary horizontal collimator.

Regular observations with the Spectroheliograph and with the register of velocities were organised by Deslandres. The results found each day were kept, and the variations considered in connection with the eleven-year Solar period. M. Deslandres insisted that the photographs given by the bright calcium line were properly described as images of the chromosphere projected on the Sun's disc. The brilliant areas are over the faculæ, and the general chromospheric réseau, as it is called by Deslandres, extends over the whole disc.

In 1898 M. Deslandres was appointed Assistant Astronomer at Meudon. He had not, however, the opportunity or means to make any great extensions. His small spectroheliograph and Velocity Recorder were brought from the Paris Observatory, and an installation was adopted so that a polar heliostat with a mirror of 0^m·3, which was available, could be utilised. Spectroheliograms of the bright line of calcium were continued, with an image of the Sun 90 mm. in diameter.

This series of spectroheliograms, continued through a whole minimum, served to establish the important conclusions that the "*réseau chromosphérique*" subsists without any great variations

over the whole disc during the Solar cycle without sensible change, and is a permanent characteristic of the chromosphere. The facular areas, on the contrary, follow the variations of faculæ and sun-spots and disappear at the sun-spot minimum.

In 1906 the effective control of the Observatory came into the hands of M. Deslandres, and, aided by a special grant, he re-equipped the Meudon Observatory during the years 1906 to 1908. An account of the new Solar outfit and of the results obtained is contained in vol. iv. of the *Annals of the Meudon Observatory*. The contents of this remarkable book are, I am sure, familiar to all Fellows of the Society who are engaged in Solar Research. All Fellows, even those who are not interested in the technical details of the instruments by which the results are obtained, will be delighted and astonished at the beautiful photographs contained in the book.

The early results with the spectroheliograph were obtained by using the whole of the bright reversal of the K line, and included

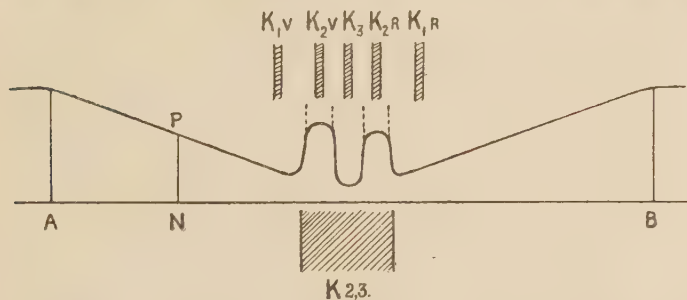


DIAGRAM I.

the doubly reversed line in the middle. With sufficient dispersion the intensity of the light in different parts of the K line is found to be as in the diagram. The line is very broad, and stretches from A to B, and the intensity of the line at any part is represented by an ordinate such as PN. If the second slit of the spectroheliograph is of width $\frac{9}{100}$ ths of an Ångström unit, indicated by K_{23} in the diagram, all the light from the two bright lines and the dark central line will go to form the picture. But if the second slit is very narrow, $\frac{3}{100}$ ths of an Ångström unit in width, then it may be placed as at K_3 , cutting off all the light except from the central black portion, or in either of the positions K_{2R} and K_{2V} , cutting off all light except from one or other of the bright reversals, or in the positions K_{1R} or K_{1V} using only light towards one of the edges of the line. The light from K_1 , K_2 , K_3 comes, says M. Deslandres, from distinct layers of the Solar Atmosphere. That from K_1 is the layer which gives the ordinary dark lines in the Solar Spectrum, the light from K_2 is from the chromosphere, the light from K_3 is from a still higher layer. When M. Deslandres became Director of the Meudon Observatory he immediately com-

menced, aided by a special grant from the French Government, to construct a large spectroheliograph which should more fully differentiate these different layers of the Solar Atmosphere.

The powerful instrument which he constructed is fed by an object-glass of $\cdot 25$ m. which receives the Sun's light reflected from a cœlostæt. The focal length is 4 metres, so that the image of the Sun on the first slit is 40 millimetres. The light is dispersed either by a Rowland grating of height 55 mm. and width 80 mm., or by three large flint prisms of 61° angle. The camera of the spectrograph is 7 metres long, the same length as that used by Rowland for his solar spectrum, a concave mirror of $0^m\cdot 40$ and 7 metres focal length being used to form the image on the second slit. The dimensions of the collimator objective and the position of the prisms or grating were carefully arranged so that the optical conditions might be satisfied to the best advantage. The image of the Sun on the second slit is very large, 200 mm. in diameter, and if the photograph were taken there a very long exposure would be required. Further, there is a certain amount of diffused light which would interfere with the purity of the image. Instead of placing the photographic plate just behind the second slit, the light is allowed to fall on another mirror of $\cdot 40$ m. and 7 metres focal length, and the beam after reflexion from the mirror is passed through a prism of 30° to get rid of the stray light and is brought by an object-glass to focus at a third slit. The plate is placed just outside the third slit and the Sun's diameter on it can be arranged to be anything from 90 mm. to 9 mm., that usually employed being 40 mm. or 60 mm.

The spectroheliograph is kept fixed. Synchronous movements are given to the receiving object-glass and to the photographic plate at the third slit. The accordance of these movements is accomplished not by mechanical means, but by synchronous electric motors. In this way a perfect synchronisation is obtained whatever relative speeds are required.

In addition to the large spectroheliograph with three slits which I have briefly described, the installation is so arranged that with the same collimator alternative optical combinations can be employed, and thus with very little trouble the observer has no less than four spectrographs which he can use at pleasure.

For the Velocity Recorder it is necessary (1) to have a large dispersion, (2) to obtain a sharp image of the isolated ray, and (3) to have a large image of the Sun, circular if possible. A mirror of $\cdot 20$ m. diameter and 4 m. focal length was first used as the objective, and when this was required for other purposes, was replaced by a simple lens of 18 centimetres aperture $3\cdot 60$ m. focus, made of glass very transparent to ultra-violet light. For the collimator a lens of ultra-violet glass of aperture 10 centimetres and focal length 80 centimetres was employed, for the camera objective a lens of similar glass of $3\frac{1}{2}$ metres focal length. The dispersion was obtained at first with a Rowland plane grating, using the spectrum of the fourth order, but afterwards

a train of flint prisms was substituted. The final image had a diameter of 140 millimetres and presents 140 sections, each section being a millimetre wide. It is not necessary for me to describe the beautiful mechanism by which the discontinuous movements are given. The time of changing from one section to the other next occupies only $1^s.5$, and it is possible to give exposures of $1^s.5$, 3^s , 5^s , $7^s.5$, or $16^s.5$ to each section as may be required by the height of the Sun, the clearness of the air, or the sensitiveness of the photographic plate. One other point should be noted. Provision is made for obtaining a comparison spectrum alongside the Solar line, when it is required.

The installation of these beautiful instruments was completed in 1908, and the first researches were directed to the different layers of the Solar Atmosphere as they are revealed by different parts of the K line of calcium. In vol. iv. of the *Annals of the Observatory of Meudon* specimens are given of the photographs which were taken. Some of them I propose to show upon the screen to illustrate the conclusions which M. Deslandres draws from them.

For comparison a photograph of the Sun taken with a photo-heliograph is shown. Such a photograph is mainly obtained from the integrated continuous bright light of the Solar Spectrum, and gives a picture of the source from which the light comes, namely, the Sun's photosphere.

The next slide shows the image of the Sun taken in what is called K light, that is, the second slit of the spectroheliograph is set some way towards the edge of the dark K line. The resulting photograph gives a picture of the layer of the Sun from which the light emanates, and it is interpreted as coming from the lower layer of the Solar Atmosphere, in which the absorption causing the Fraunhofer lines takes place.

The third slide shows a photograph taken with one of the bright calcium lines K_2 , the one to the violet being used in this instance. This double line of calcium K_2 is bright all over the Sun's disc, though much less bright than over the faculæ, and further, the bright line is prolonged beyond the limb. The name chromosphere has been given to the layer which gives bright lines in the spectrum at the Sun's limb. M. Deslandres concludes that the bright K lines seen on the Sun's disc, as well as its limb, come from the same layer of the Solar Atmosphere. The photograph on the screen taken with one of the bright calcium lines represents, then, the Solar Chromosphere projected on the Sun's disc.

Above this layer there is another represented by the dark reversal between the two bright K lines. This is called K_3 , and the photograph shows this upper layer of the Sun's Atmosphere.

Prominences are also shown on the photographs of the K_3 layer with the same exposure as that required for the disc. The base of the prominence is sometimes seen projected on the disc, and sometimes it is on the limb, and sometimes on the half of

the Sun's disc turned away from us. The exact situation of the prominences relatively to the limb and to the lines shown on the disc is thus obtained.

As we pass from lower to higher layers of the Solar Atmosphere, the dark spots which are the principal feature of the surface diminish in area, while the bright areas increase and encroach on the spots. But the most striking characteristic of the highest layer is the black lines. These are often very long and do not appear, or only faintly, on the K_2 or chromospheric layer. To these black lines M. Deslandres has given the name of filaments, and to others less sharp and less dark the name of alignments. These filaments and alignments form a complete network covering the whole disc. M. Deslandres considers that the filament of the highest layer has the same importance as the spot of the lowest layer. The filaments persist sometimes like the spots for several rotations, and the Velocity Recorder shows them to be the seat of special disturbance. As the spots are centres of a vortical motion round a radial axis, so the filaments are centres of rotation about a transverse one. Spots and filaments are equally important in the consideration of the circulation of the Solar Atmosphere. Spots may be compared with depressions or cyclones on the Earth's Atmosphere, and filaments with anti-cyclones.

In the following year, 1909, M. Deslandres and his assistant and colleague M. d'Azambuja, to whose services M. Deslandres constantly pays tribute, made observations with the same instruments on the hydrogen lines, particularly the red line $H\alpha$. The extreme width of this line is 1.24 tenth-metres, and 0.90 tenth-metres if the diffused parts at the edges are cut off. By using a very narrow slit and isolating the part of $H\alpha$ distant $\frac{4.7}{100}$ ths to $\frac{6.3}{100}$ ths of a tenth-metre from the centre, a photograph of the Sun at the Fraunhofer lines level is obtained. When a part of the line between $\frac{1.0}{100}$ ths and $\frac{4.2}{100}$ ths hundredths of a tenth-metre from the centre is isolated, a photograph at a higher level is obtained; and, isolating the centre of the line, a photograph of the highest level of the Solar Atmosphere. The delicacy of the instrument and the manipulative skill necessary to isolate such small fractions of the width of a line will appeal to everyone who has used a spectroscope.

The characteristics of the three layers are briefly these:—The images of the highest layer are very simple. They show the same bright areas as are found in the K_3 images, and the same black filaments and alignments. The mean layer is much more complex, and shows best the remarkable flocculi which constitute the solar vortices discovered by Mr. Hale. The lowest layer shows the same facular areas as are found in calcium photographs, but dark instead of bright.

The slide taken from pl. 46 in vol. iv. of the *Annals of the Meudon Observatory* shows a photograph of these three layers on 1909 August 5. The simplicity of the highest layer as compared

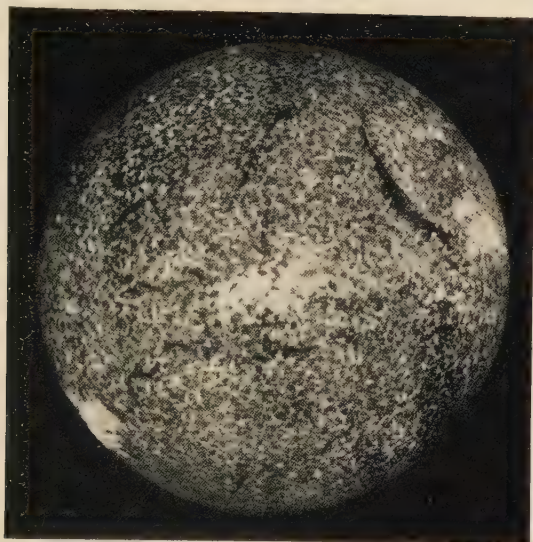


Fig 1.—Slit at centre of K line of Calcium.

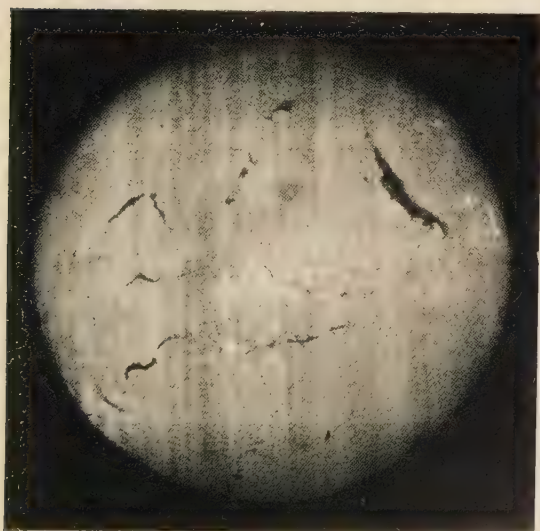


Fig. 2.—Slit at centre of Hydrogen line $H\alpha$.

SPECTROHELIOGRAMS OF HIGHEST LAYER OF SUN'S ATMOSPHERE,
1910 MARCH 21.

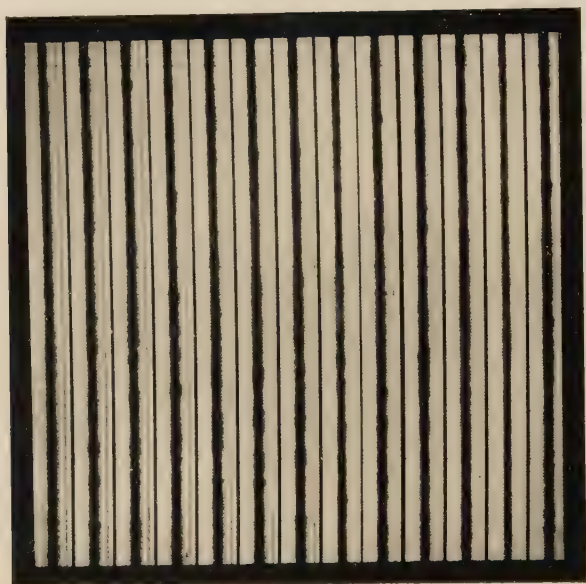


Fig. 1.—Velocity record with $H\alpha$ line, showing variable width and sinuosity.

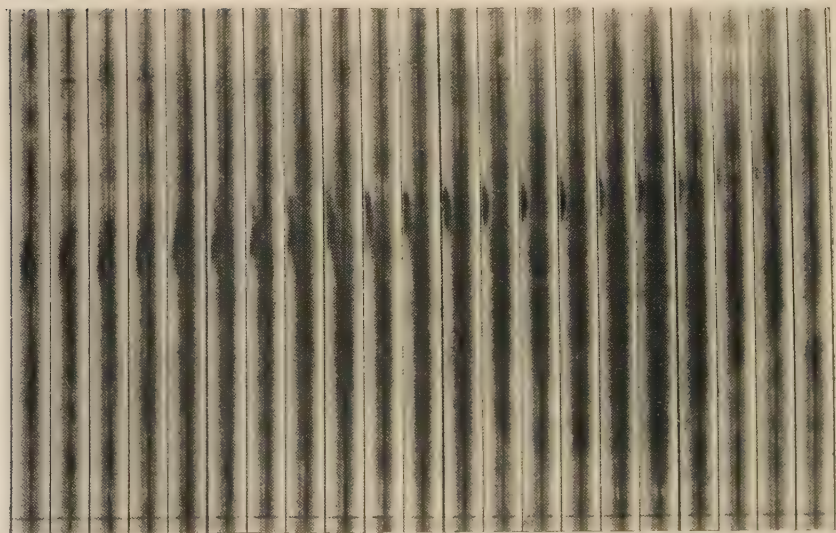


Fig. 2.—Velocity record with K line, 1910 April 11, showing large displacement towards the violet.

with the others will be clearly seen, as well as the presence of the bright areas and the dark filaments. Pl. 36 of the same volume shows photographs taken in different parts of the $H\alpha$ line, compared with the mean calcium photograph. The gradual change of character is shown in a striking manner. M. Deslandres has given special attention to the highest layer. The remarkable results he has obtained in the correspondence of the hydrogen and K_3 photographs and the extraordinary character of the filaments and alignments are well shown in the photographs of March 21 and April 11, 1910. The bright patches in the photographs of the higher layers lie above the faculæ; but the dark parts are quite different—below them are spots, above them are filaments.

We come now to the results obtained with the Velocity Recorder. This instrument makes it possible to determine the radial velocity at all points of the Sun's disc, and in addition the variation in width and character of whatever spectral line is studied. The general character of the photographs taken with this instrument are seen in the photograph of 1909 August 23, which is thrown on the screen. The sinuosities of the line and the variations in character of the dark central K_3 and the bright K_2 lines on its sides can be well seen. Using the side of the slit as a base line, the distances of the K_3 line from it can be measured for all parts of the Sun, and then by aid of the comparison spectrum which gives a fine line parallel to the edge of the slit, to serve as a fundamental line of reference, the corresponding radial velocities can be found at all points on the Sun's disc.

In the photograph taken 1910 April 11 it will be seen how the Velocity Recorder may reveal phenomena which would be wholly lost by the spectroheliograph. The dark filament in the middle of the photograph has a large upward radial velocity, which throws it towards the violet to such an extent that it would not fall upon the narrow slit of the spectroheliograph.

The slide from a diagram in the *Annals of the Meudon Observatory* shows what a mine of information is contained in each of these registers. At the same time it indicates the amount of labour necessary to extract this information. Thousands of measurements have been made on a single photograph and the radial velocity determined at as many points on the Sun's disc. At the centre of the disc there are vertical velocities on the Sun's surface. They vary from 200 metres to 2 kilometres per second.

The most general conclusion which M. Deslandres draws from these velocity records—and he gives it with some reserve, owing to the limited number of plates which have been measured—is that the bright areas are descending and the dark filaments are ascending. He points out that this is what should be expected, for the descending vapours are gaining and the ascending vapours losing heat.

Further, in the areas around the faculæ the vapours are generally ascending. Thus the faculæ and their entourage form, he says, a complete vortex analogous to the convection currents in

liquids heated from below. Each gaseous molecule rises in the circumfacula and approaches horizontally to the facula, then descends in the facula, and spreads out horizontally again, thus describing a closed curve. If for any reason the descending velocity on the facula increases, the vapour pierces the lowest layers and forms a hole which is a sun-spot. On the other hand, increased velocity in the ascending currents gives rise to prominences. In the diagram the velocities in a small region round a facula are shown, those of descent being indicated by lines \ and those of ascent by lines /, the longest line corresponding to about 2 km/sec.

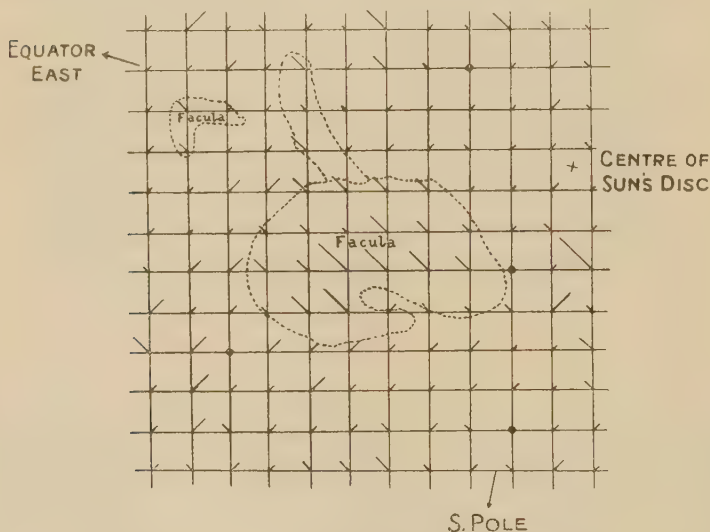


DIAGRAM 2.

M. Deslandres attempts a general explanation of the circulation of the Solar Atmosphere. Taking the observations of M. Bernard of the cells which are formed when a liquid is heated uniformly at its base as furnishing a model, he imagines vortices of a similar character in the Solar Atmosphere striving to maintain equalisation of temperature. The network of bright lines shown in the high-level calcium photographs are the boundaries between neighbouring vortices, which are rotating in opposite senses exactly like two geared toothed wheels. The filaments and alignments with the most brilliant of the facular areas form a similar system on a larger scale and at a higher level. Finally, from the positions of the filaments relative to the poles, he concludes that these great currents are englobed in a general circulation extending from the equator to the poles.

M. Deslandres remarks that the explanation, of which I have been able to give the barest outline, is inspired by the analogy of

the terrestrial atmosphere, and has the advantage of being simple. Its aim is to provoke new researches in a well-defined direction, capable of leading to other verifications. It will be necessary above all to prosecute researches on radial velocities, to extend them to other lines, and if possible to different parts of the hydrogen lines.

In his most recent researches M. Deslandres has considered the relationship between prominences and the filaments and alignments found in the highest layers of the Sun. In general, at a point of the limb where there is a prominence a filament or an alignment usually ends. Comparison with observations of prominences of the limb by M. Ricco shows that prominences stretch across the Sun along these alignments. The Velocity Recorder shows that near the Sun's limb the base of a prominence has a more rapid rotation than the K_3 layer. This is found to hold for 87 per cent. of the cases examined. M. Deslandres shows how these point to the existence of a magnetic field in the higher layers of the Solar Atmosphere, and how they accord with the differences in the numbers of prominences visible at the two limbs. M. Deslandres always keeps in mind the ultimate object of his researches—the determination of the constitution and the circulation of the Solar Atmosphere. It is for the combination of this philosophic spirit with the great skill he has shown in devising and perfecting the necessary apparatus, and the assiduity with which he has pursued his researches for more than twenty years, that your Council have awarded the Gold Medal to M. Deslandres.

The President then, delivering the Medal to M. Roux, Secretary of the French Embassy, addressed him in the following terms:—

M. Roux,—I beg to thank you for the honour you have done the Royal Astronomical Society in so kindly appearing to represent your distinguished countryman.

In handing you this Medal for conveyance to M. Deslandres, I beg you to assure him of our high appreciation of the great services he has rendered to Astronomy by his investigations into the Physical Nature of the Sun. We wish him health and strength that for many years he may continue to enrich our science, and to the Meudon Observatory continued and increased prosperity, under his direction.

Address delivered by the President, on presenting the Jackson-Gwilt Medal and Gift to the Rev. T. H. E. C. Espin.

The Jackson-Gwilt Medal has been awarded to the Rev. T. H. E. C. Espin for his observations of the Spectra of stars and his discovery of Nova Lacertæ.

Mr. Espin has been a Fellow of our Society since 1878, and for 35 years he has been a most assiduous observer of Variable stars, double stars and Stellar Spectra. In 1889 he published in the *Monthly Notices* a Catalogue of all the stars then known to be of type iv. It contains 113 stars, of which over 50 are his own discoveries. At the same date he had discovered 400 stars of type iii. Year by year from 1887 to 1896 he has published in the *Astronomische Nachrichten* catalogues of stars with peculiar spectra containing altogether no less than 1180 stars. These catalogues are of special value, as the stars are generally too faint to appear in the Harvard Catalogues of Spectra.

In 1890 Mr. Espin brought out a new edition of Mr. Birmingham's Catalogue of Red Stars. He added his own and other new discoveries and carefully verified the colours given by other observers.

In 1893 he edited the fifth and enlarged edition of Webb's *Celestial Cycle*, and incorporated in this well-known work the many new discoveries made in the interval from 1881 to 1893.

In 1900 Mr. Espin turned to double star observations. He set himself the task of examining all the stars in the Bonn Durchmusterung in the Zone 44° to 55° N. declination, and discovered 1191 new double stars, of which about half have a separation of less than $5''$. As in his observations of the Spectra of stars, he has carried out a useful and well-considered programme of work with great perseverance.

On 1911 December 30, while in pursuance of these systematic observations, Mr. Espin discovered Nova Lacertæ. It is the watchers of the skies who find new planets and new stars.

I have much pleasure, Mr. Espin, in handing you this Medal, and assuring you of the high appreciation of the Council and Fellows of this Society of your Astronomical labours.

The Meeting then proceeded to the election of the Officers and Council for the ensuing year, when the following Fellows were elected:—

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Vice-Presidents.

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